# Instrument characterization from telemetry data

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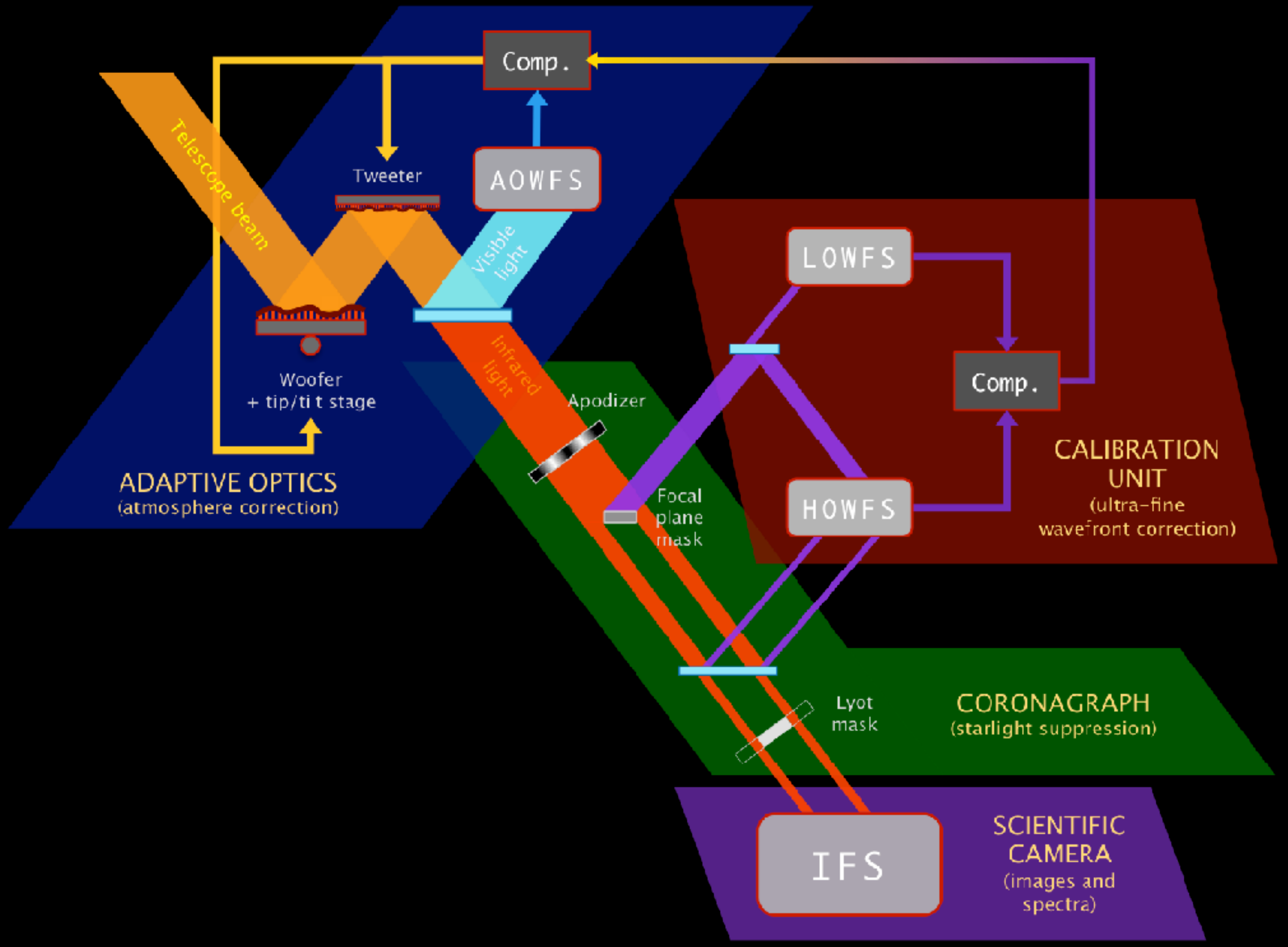
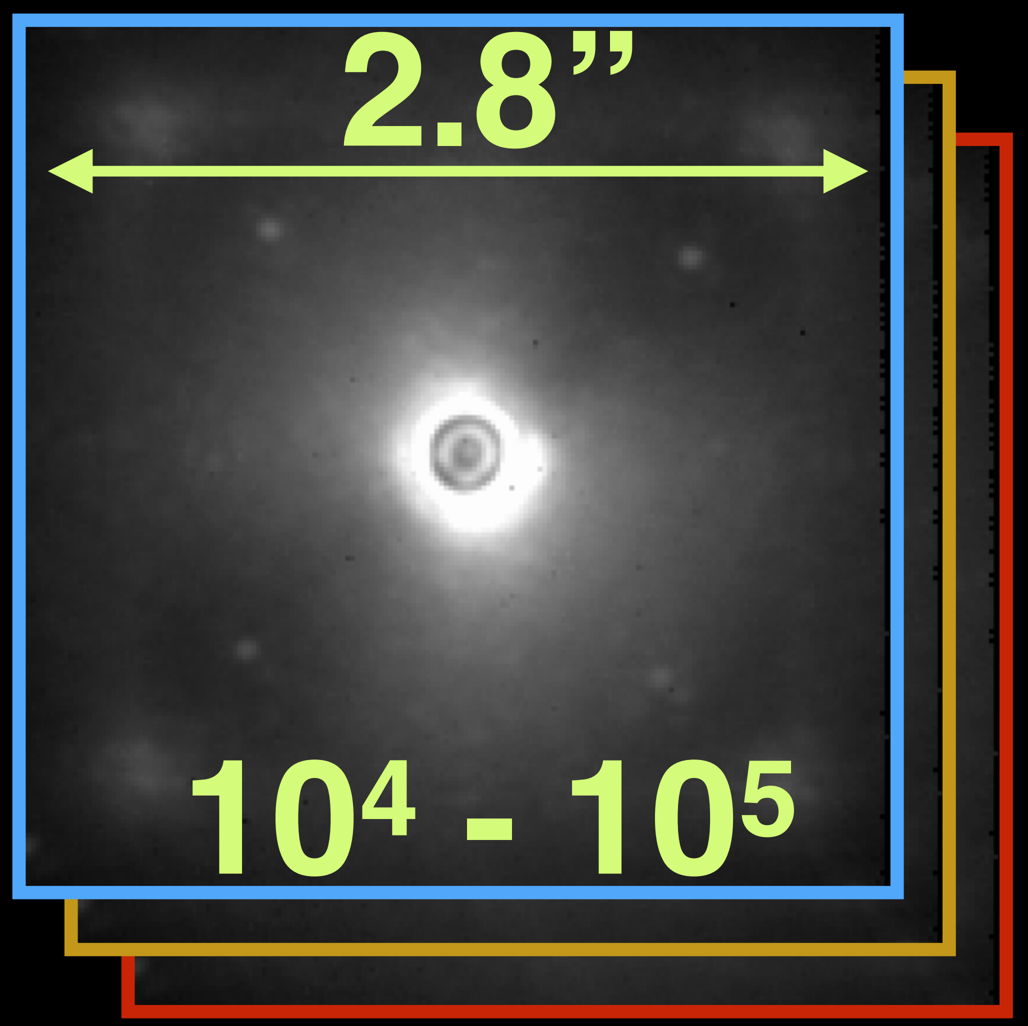
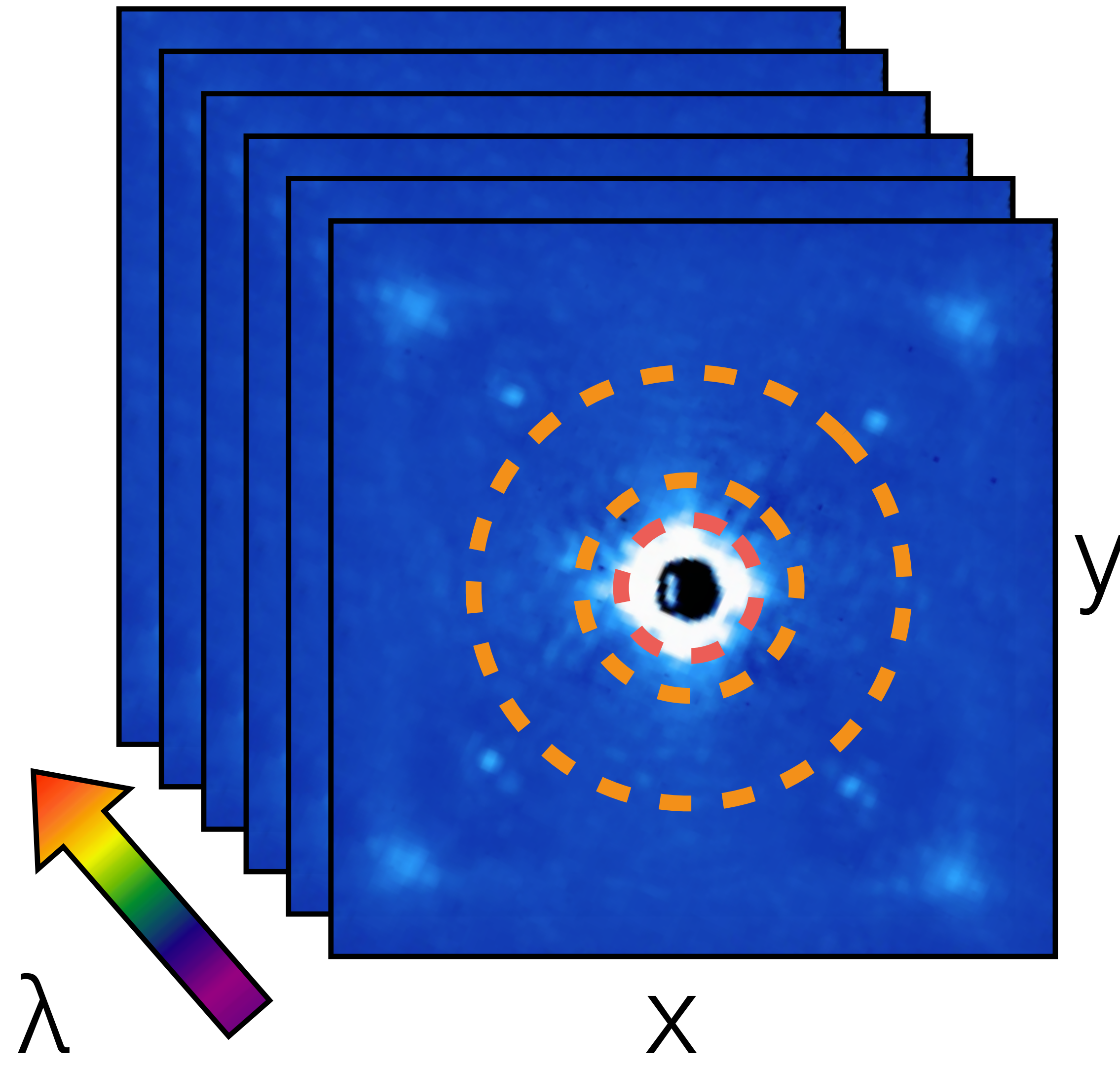
# Gemini Planet Imager




Credit - Paul Langlois

# Every GPI image has environment & performance data



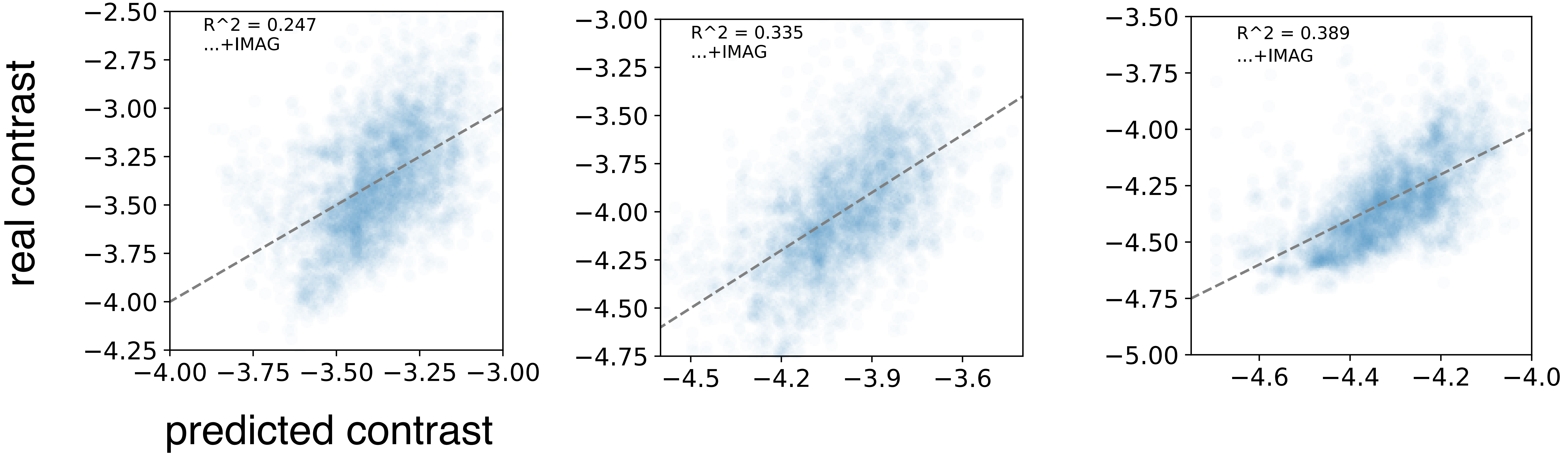

- raw image contrast @ 0.25”, 0.4”, 0.8”
- ~ WFE
- ~ AO tip/tilt & focus vibration
- environment:
  - seeing (Gemini MASS* & DIMM)
  - wind, temperature
- *Similar analysis for NIRC2 by Jerry Xuan (Pamona) ongoing*

* MASS quit working April 2016

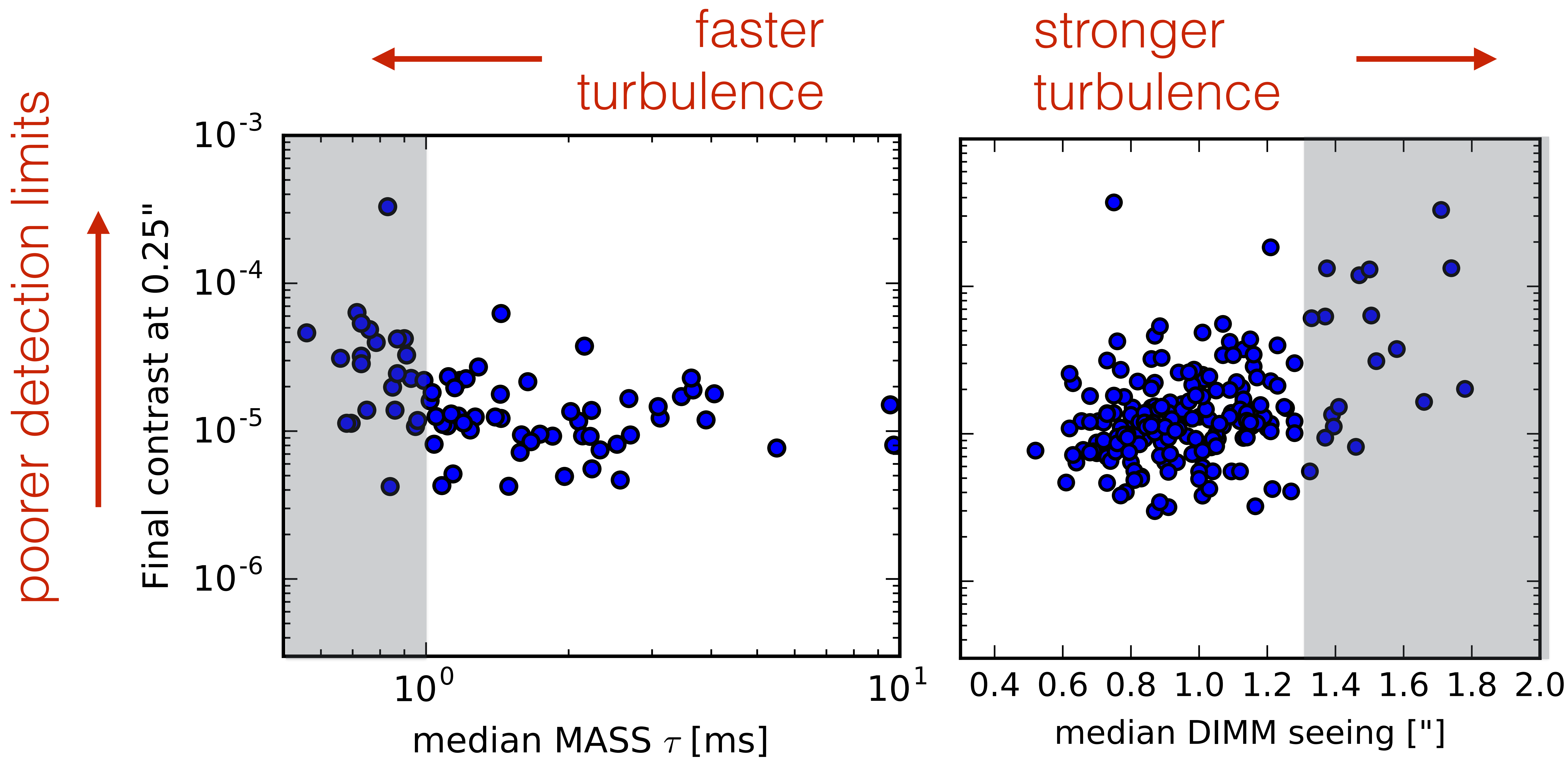
# environment parameters alone explain 25-40% of GPI raw contrast variation

- Tau
- DIMM seeing
- dT = abs(AO - amb)
- I mag

0.25” $R^2$=0.25 0.4” $R^2$=0.33 0.8” $R^2$=0.38

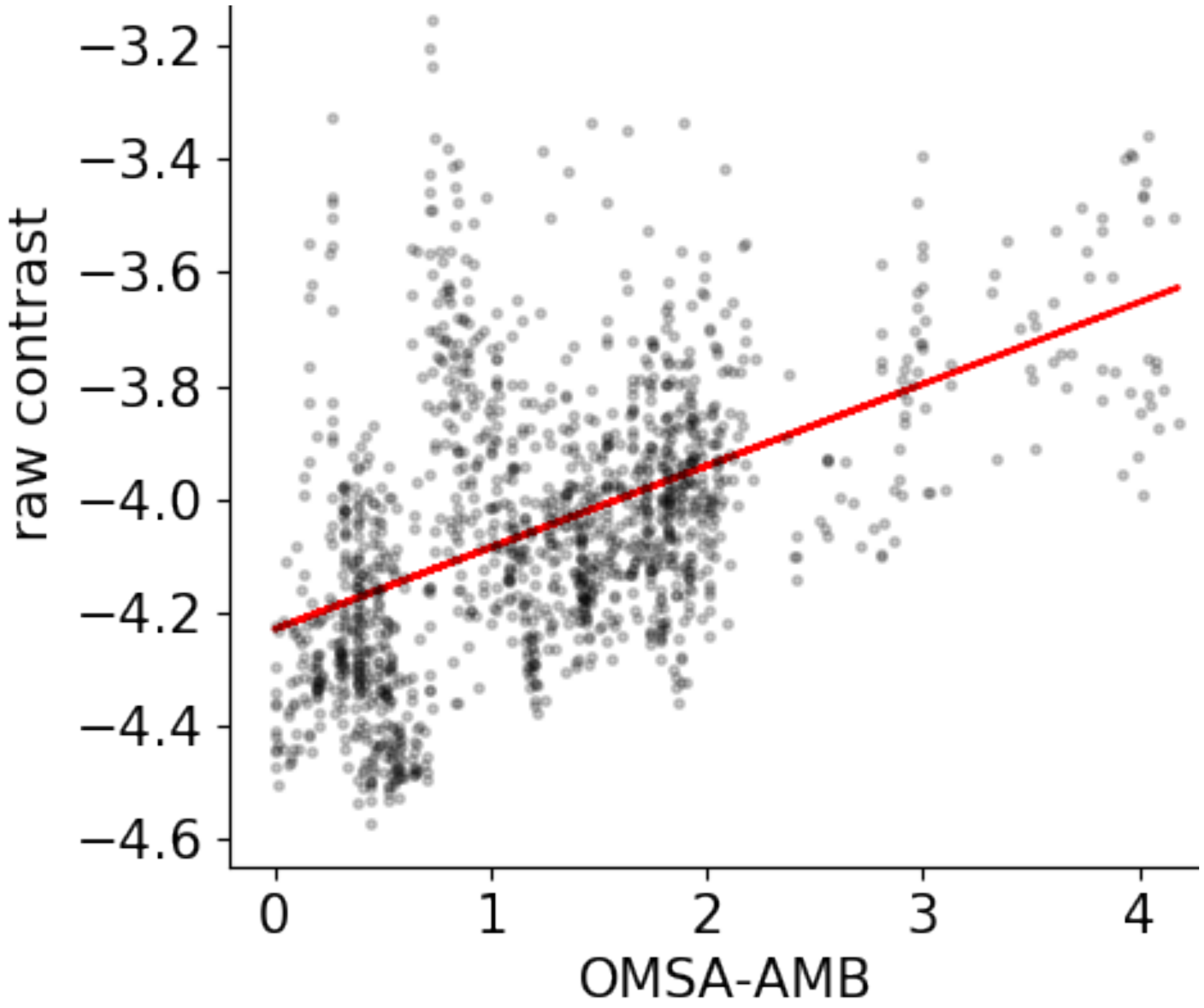


# Tau governs final GPI contrast more often than raw seeing does

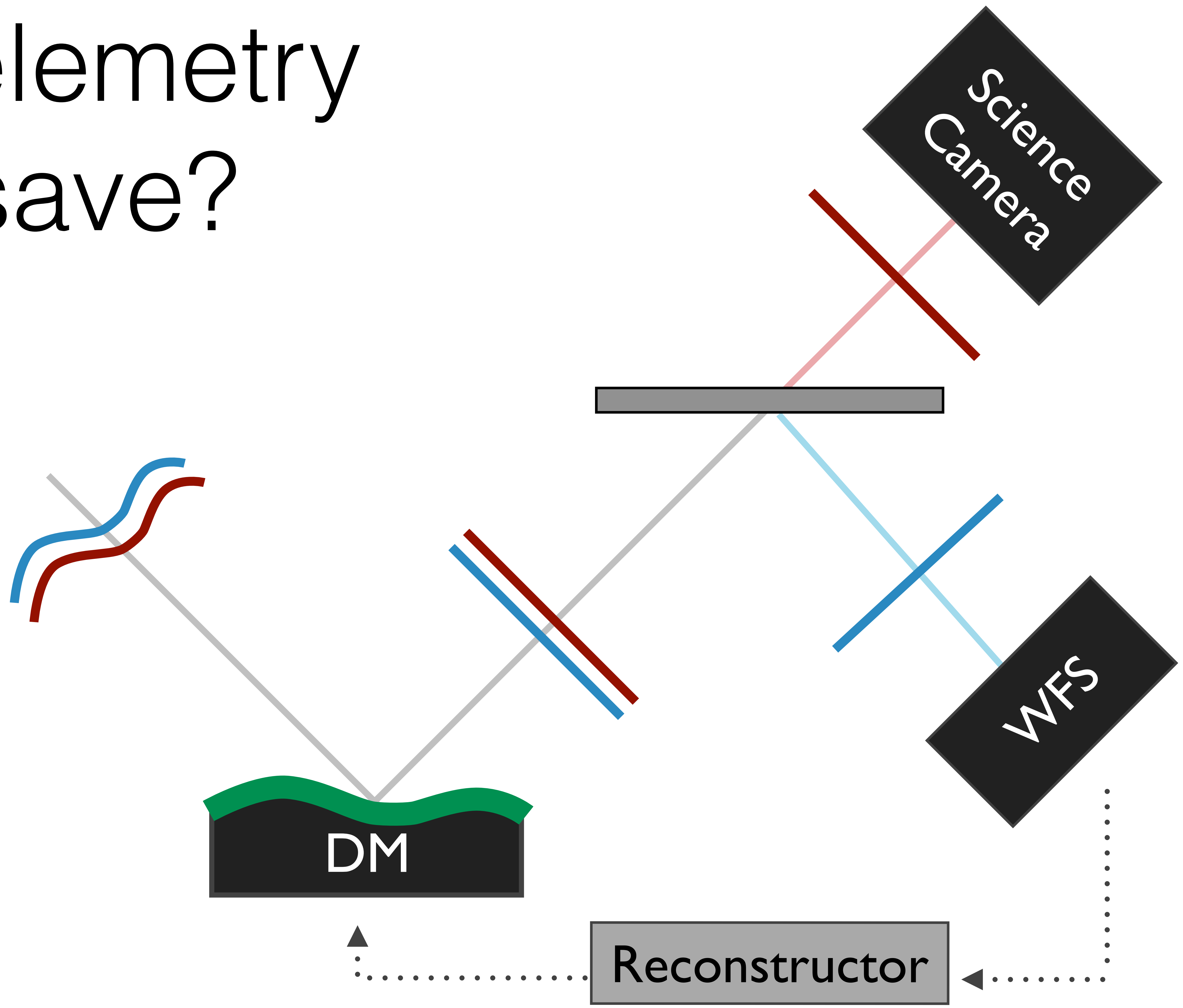


# Temperature disequilibrium degrades GPI performance

**Melisa Tallis**



# What AO telemetry can we save?



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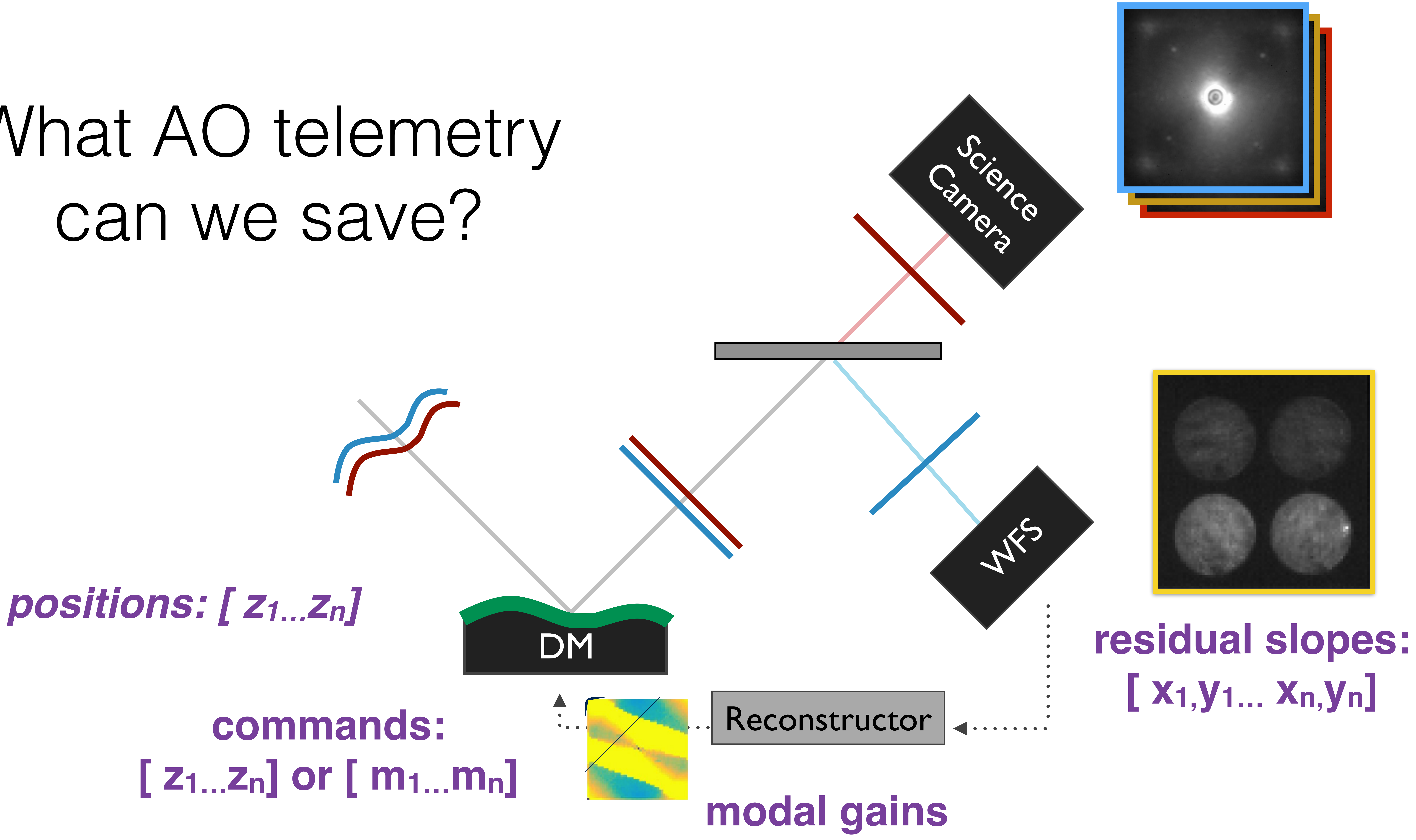
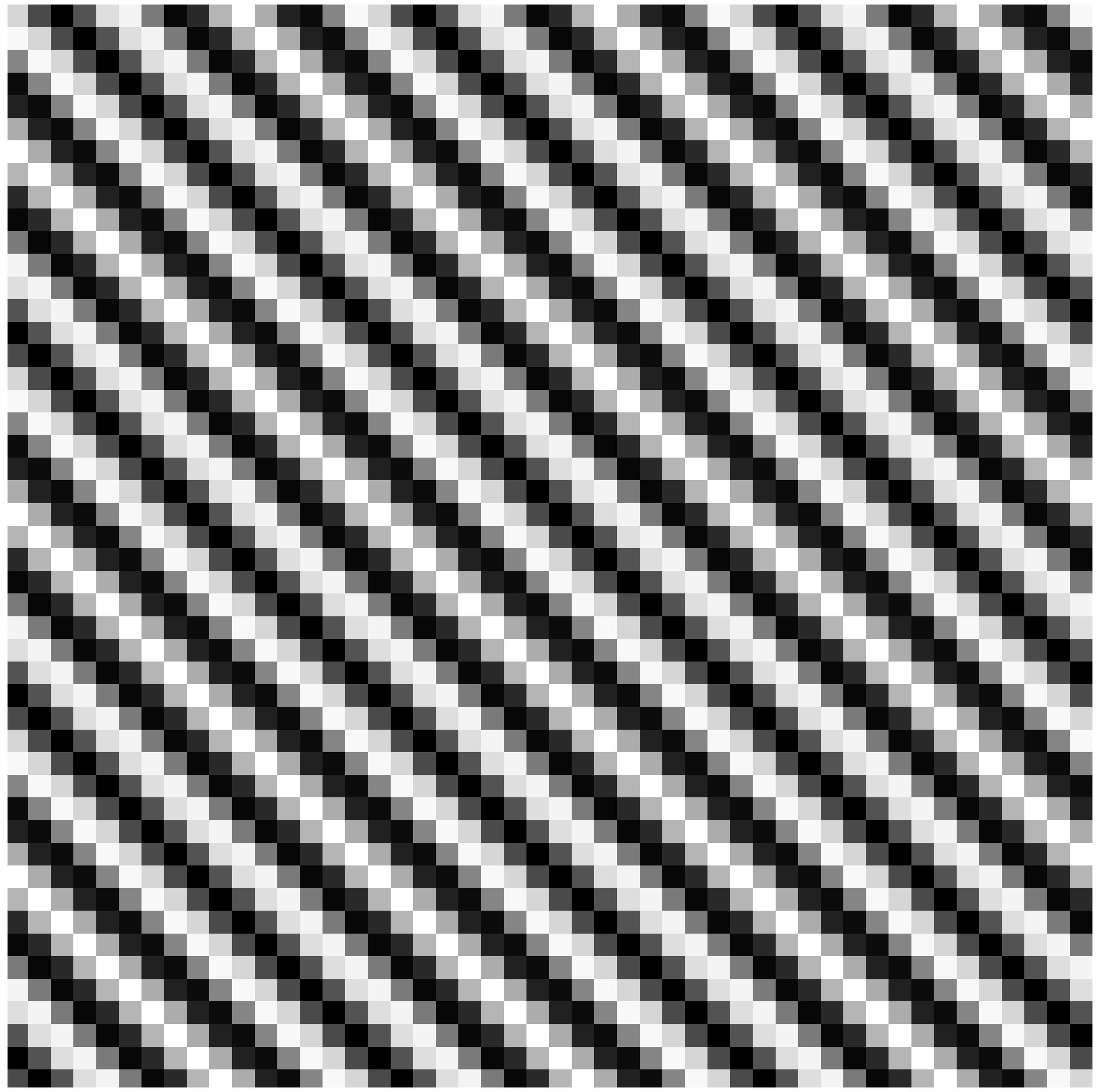
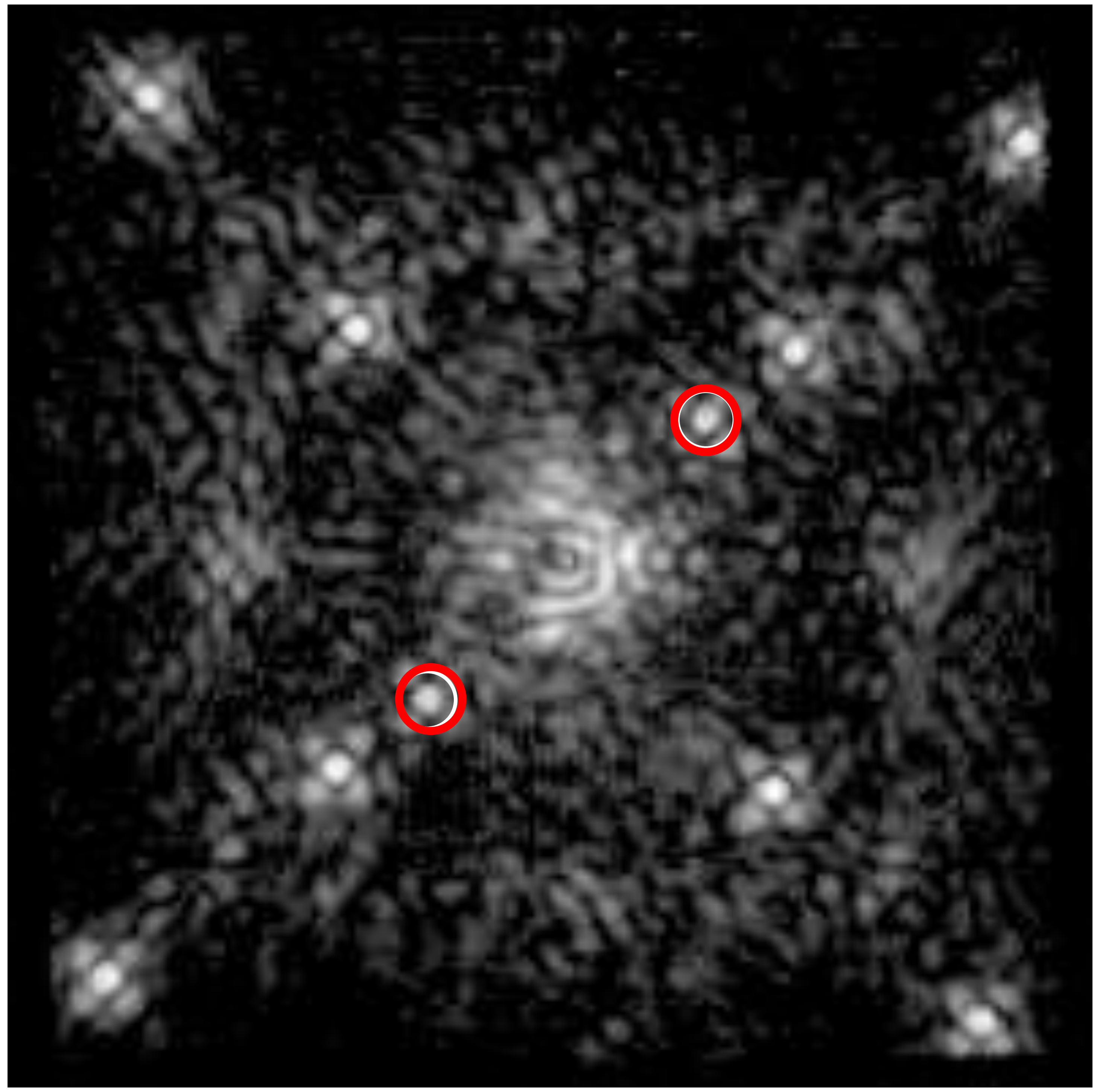


# GPI uses a Fourier modal basis set with individually controlled gains

(spatial) mode



PSF



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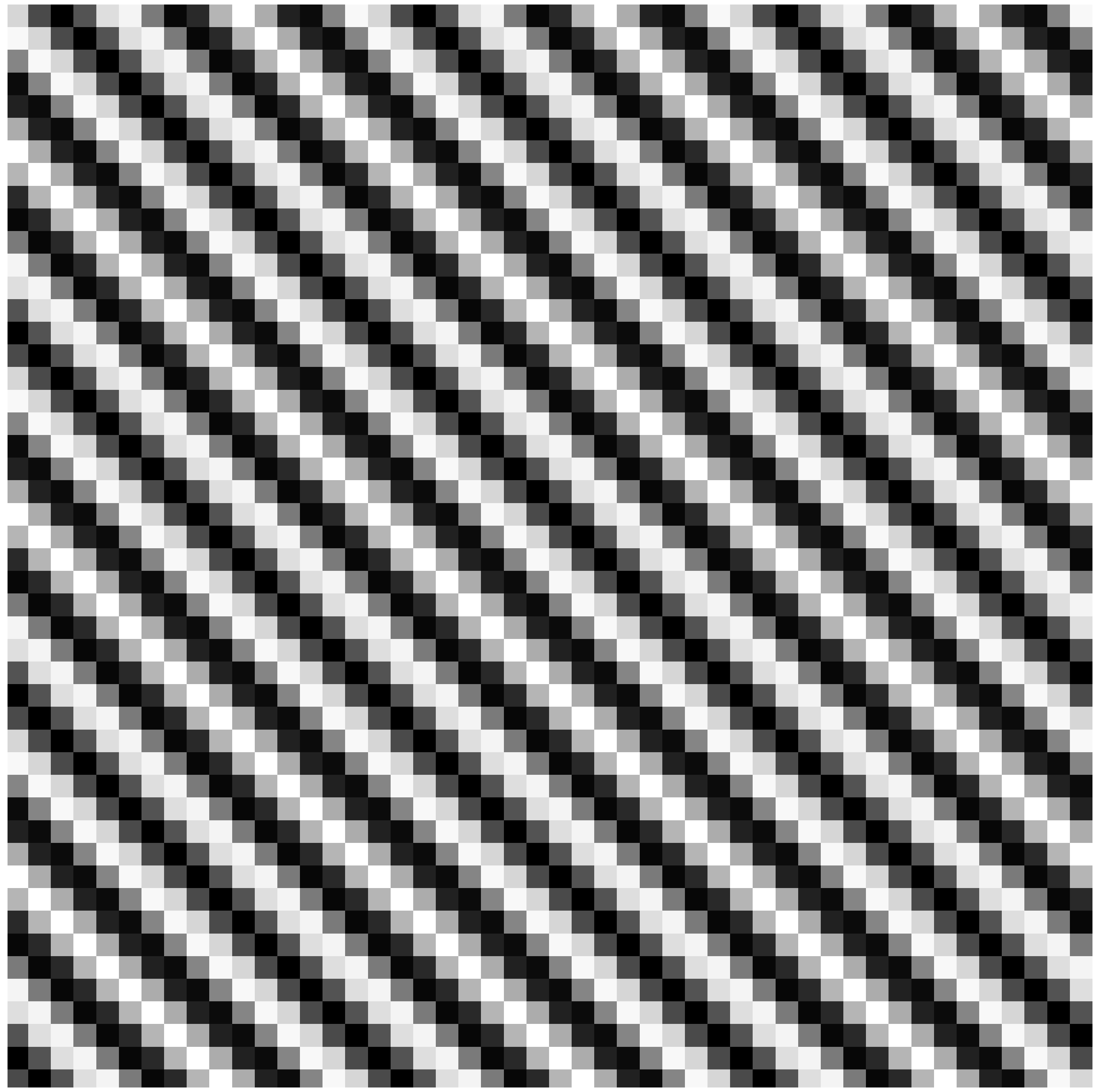
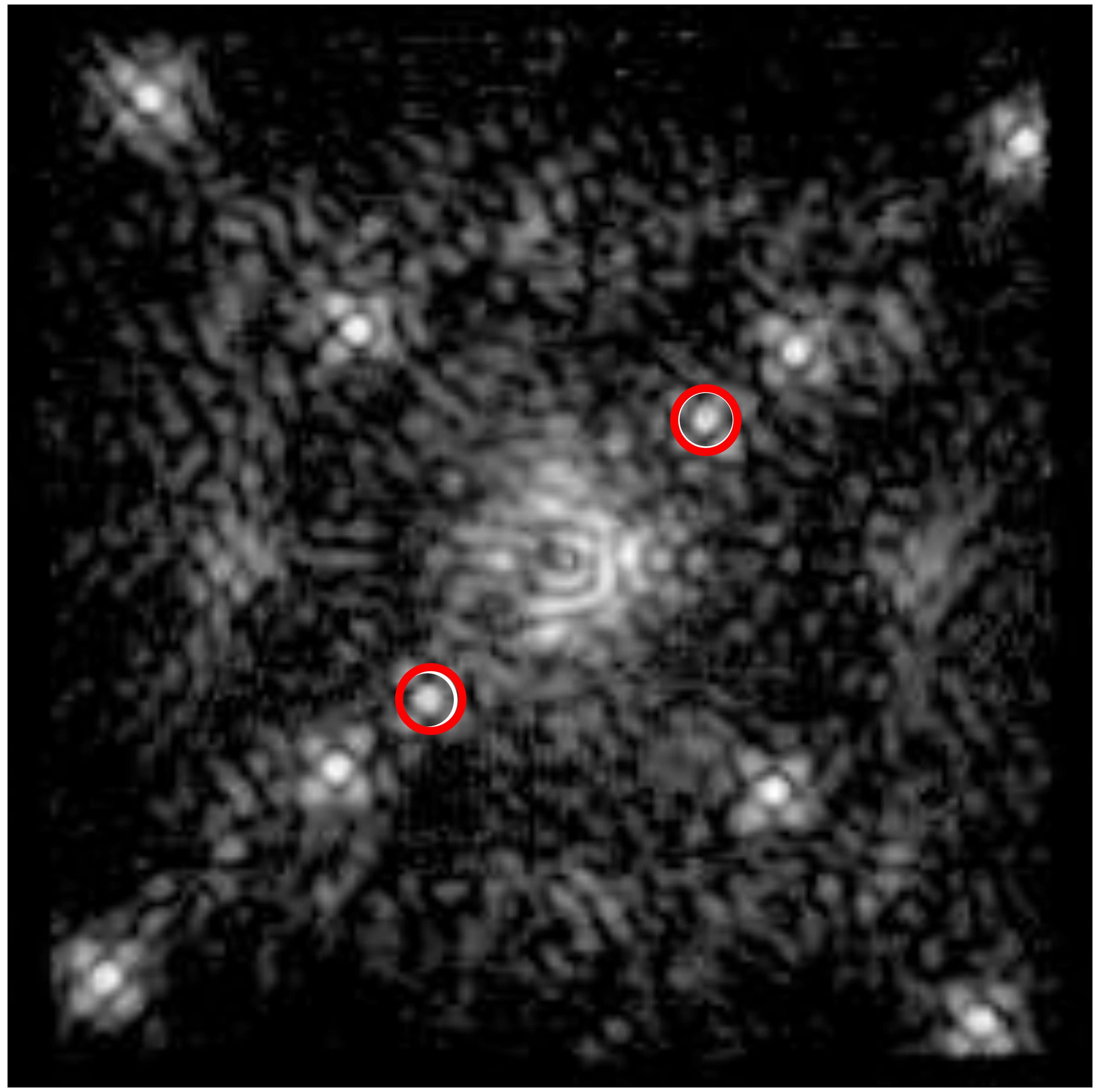
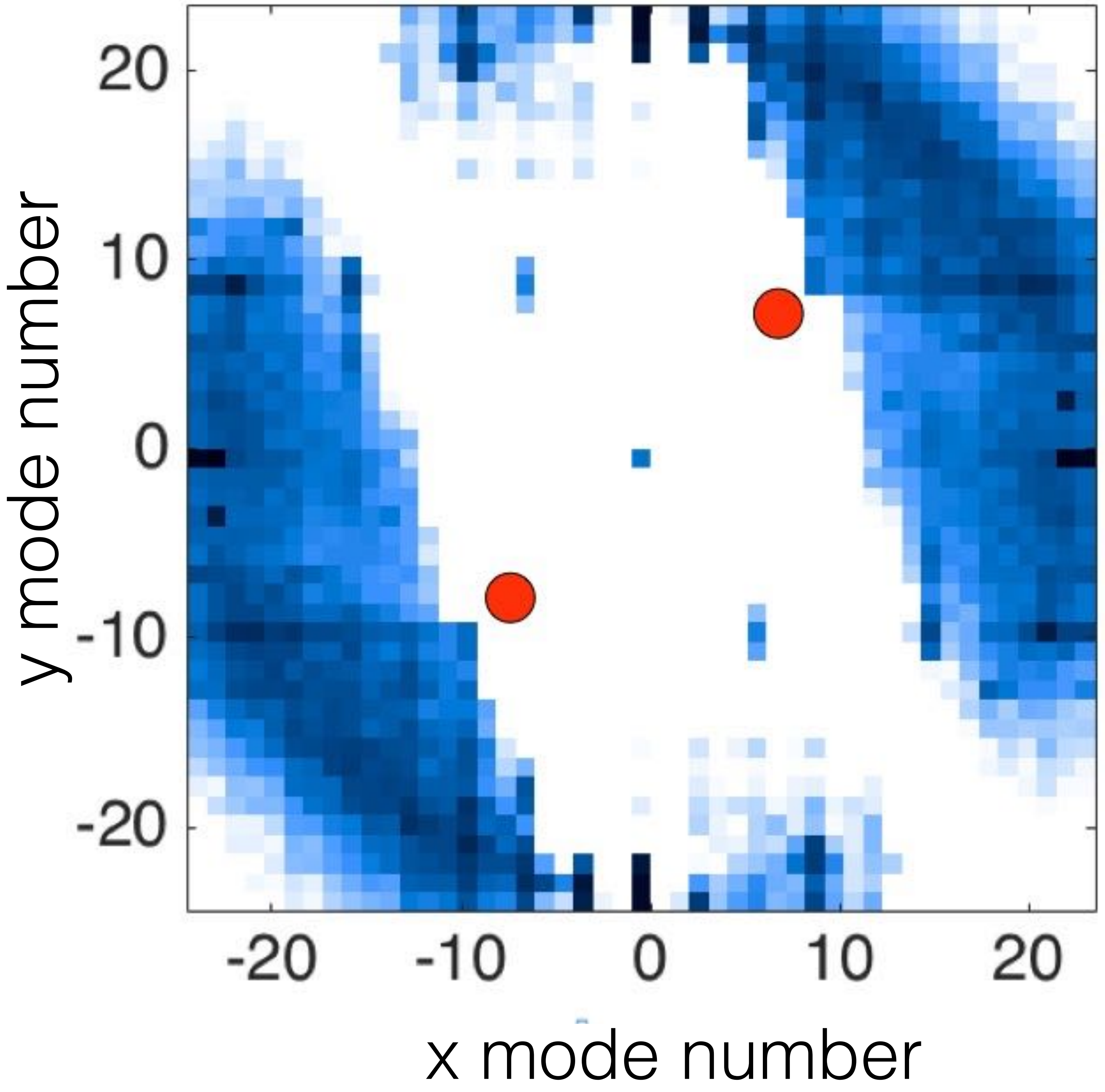


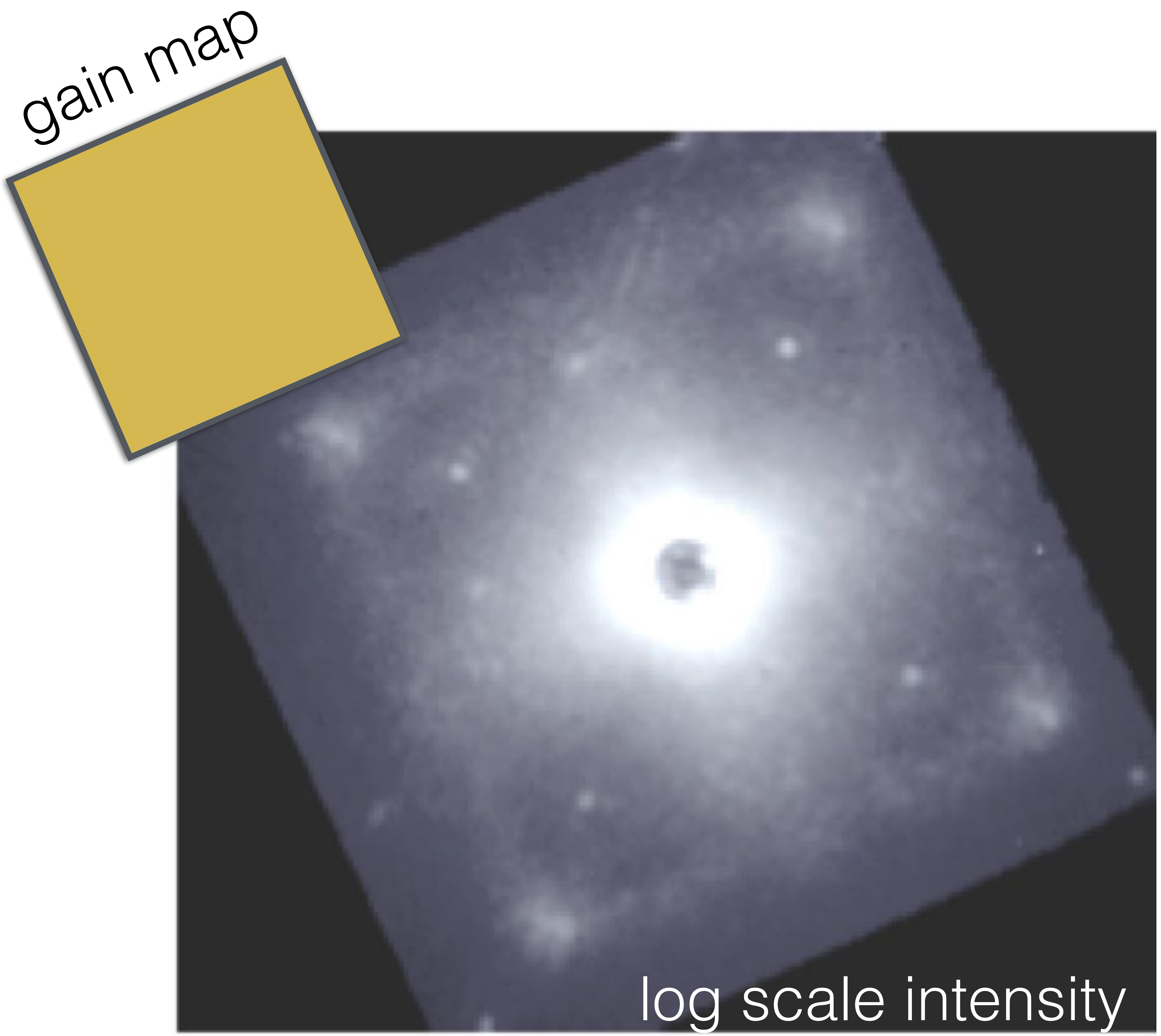
PSF



modal gain map

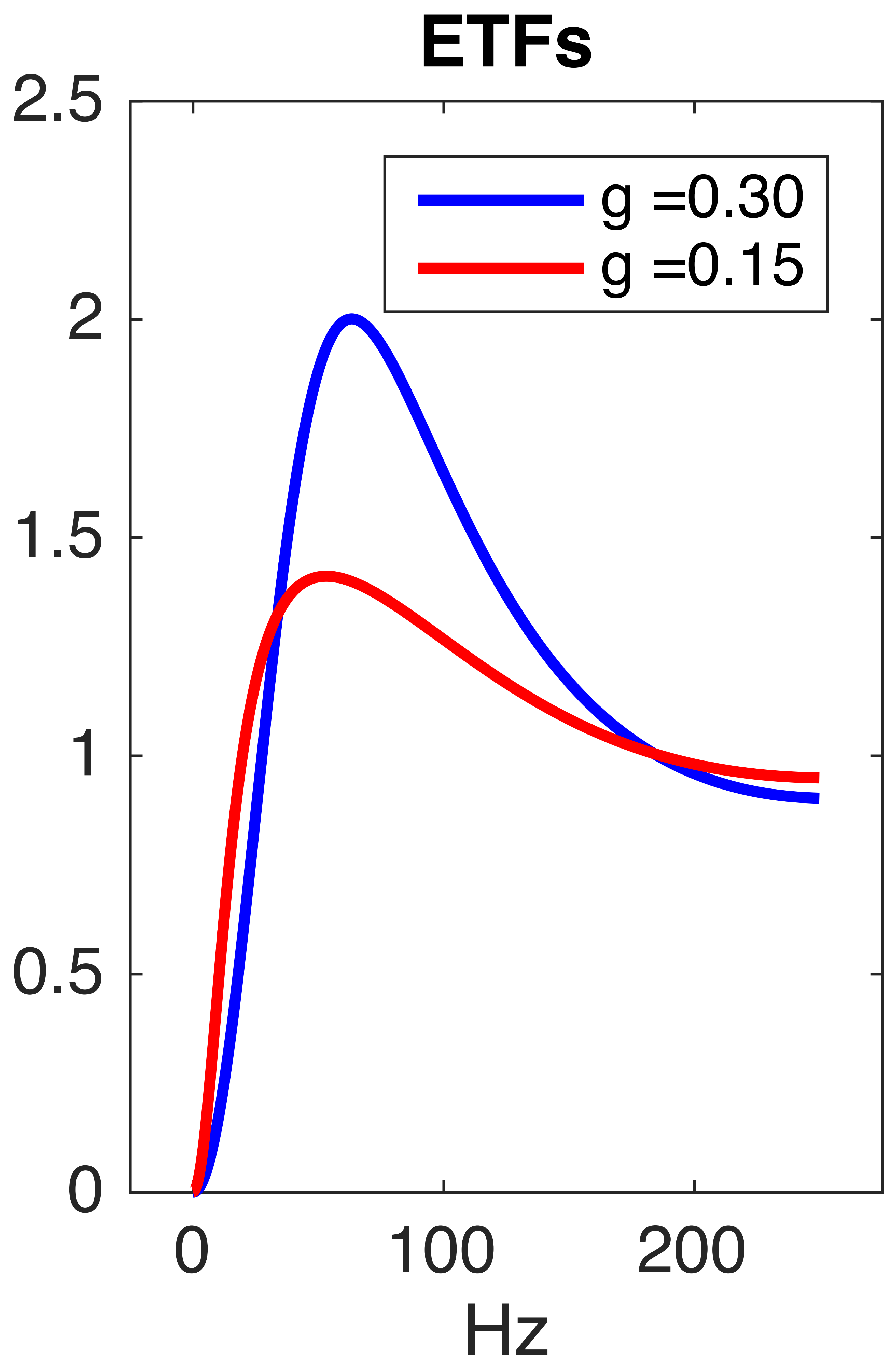


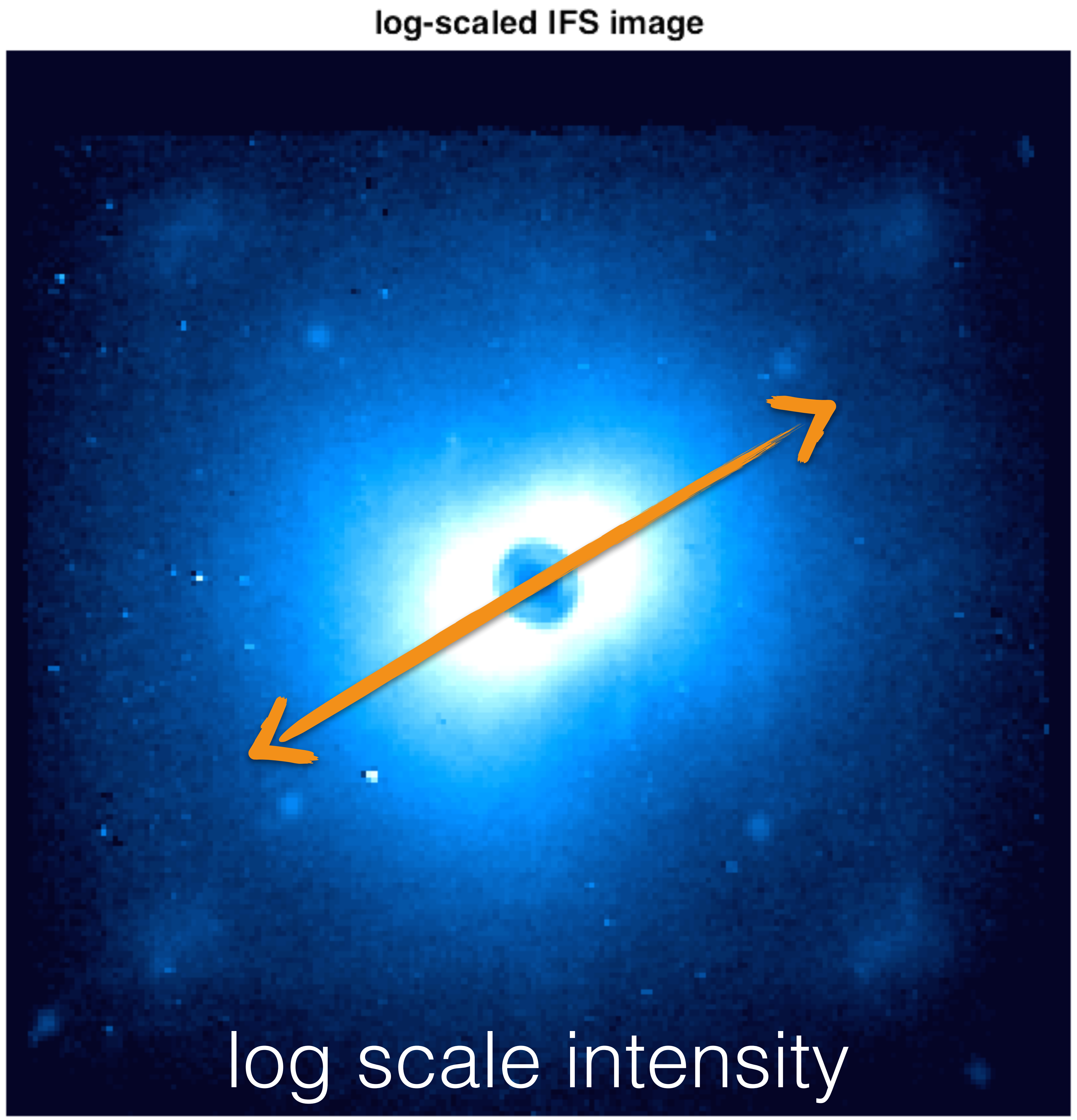
# square vs round dark hole



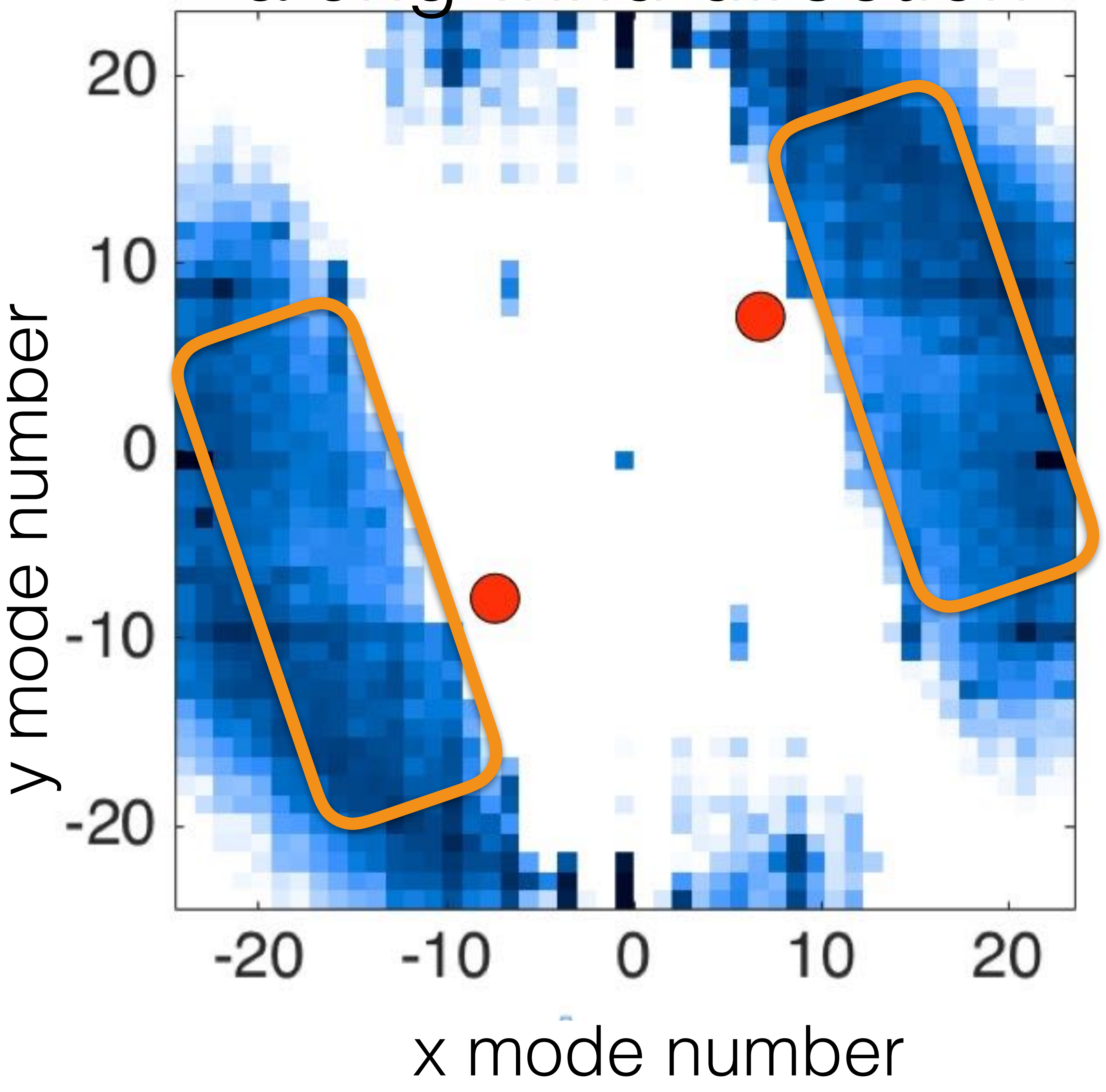
# square vs round dark hole

# Gains optimized every 8 sec



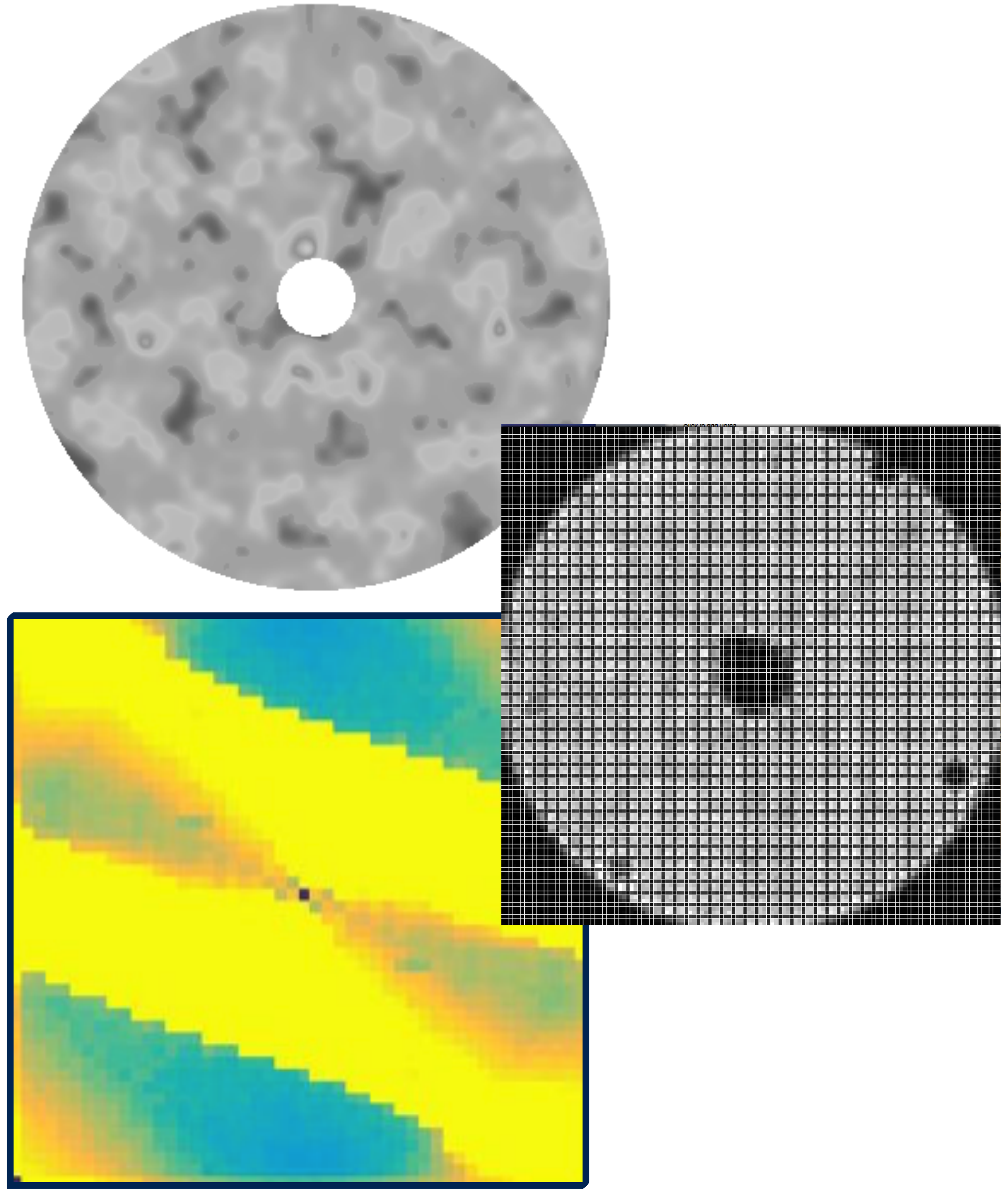




lag errors -> gains lower along wind direction



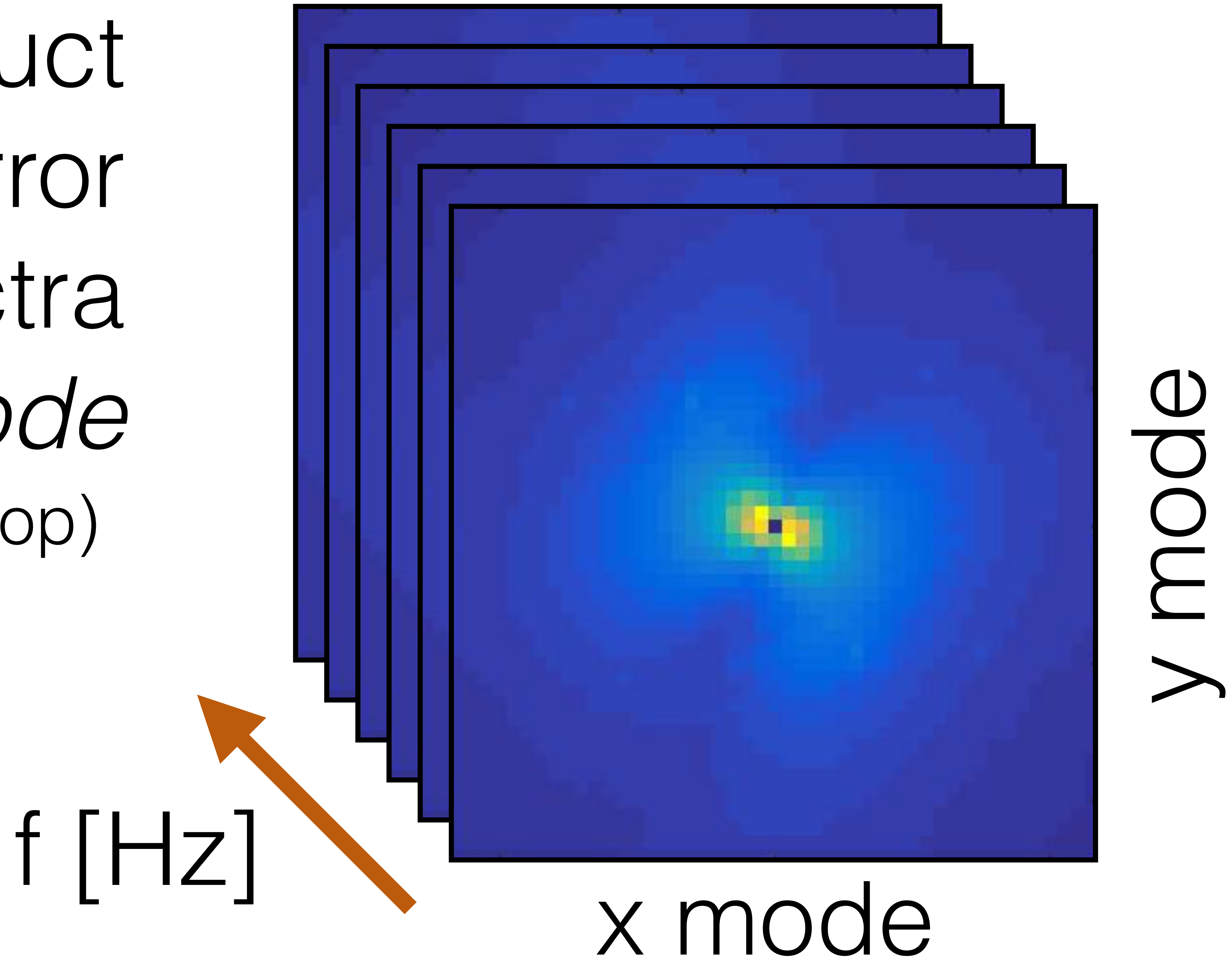
# Manual AO telemetry sets record detailed information

5 - 60sec

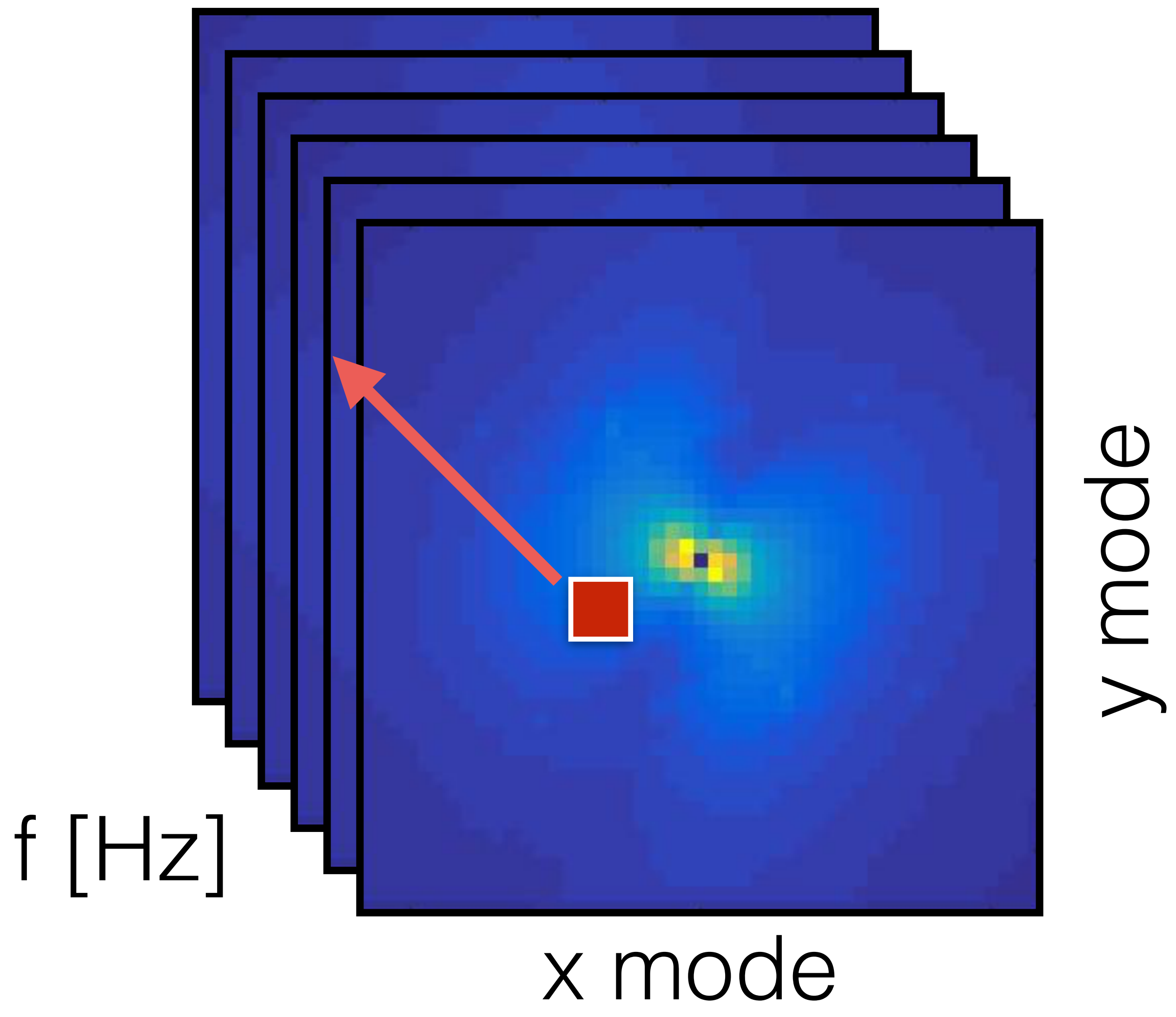


Full data rate
>1GB / min

reconstruct
wavefront error
power spectra
for *each mode*
(closed & open loop)

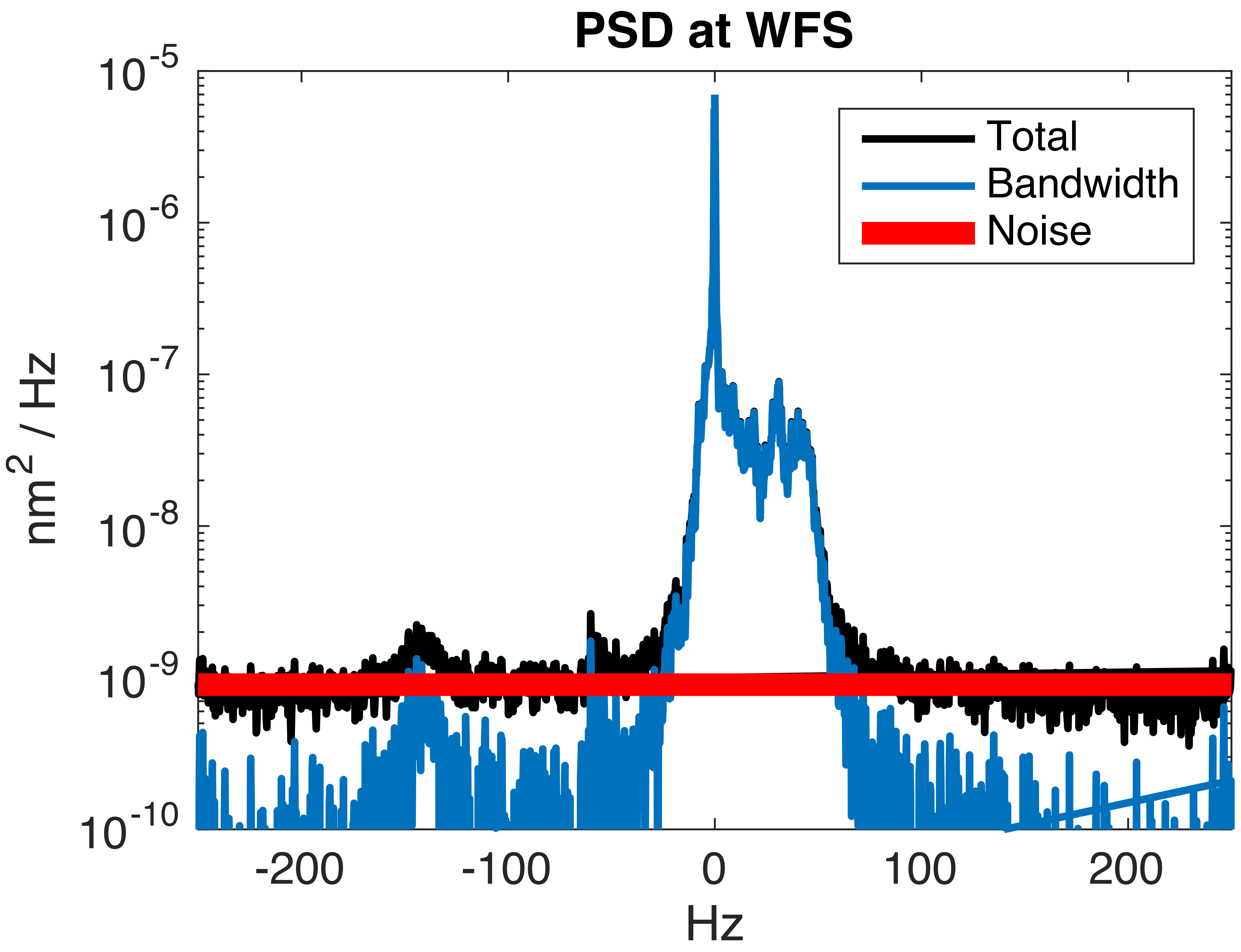


# AO WFE : bandwidth & noise




PSD for mode

$[x_i, y_i]$

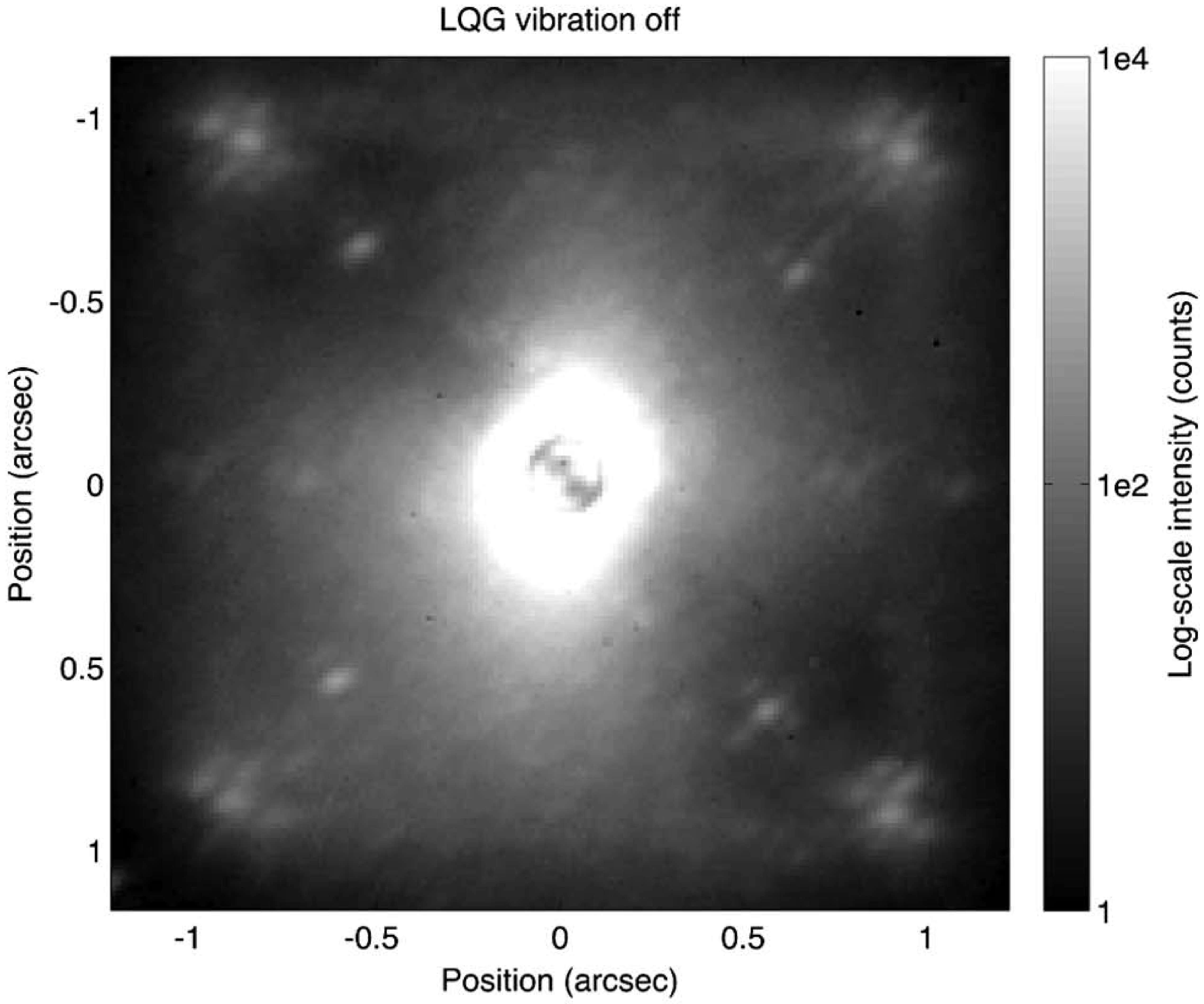


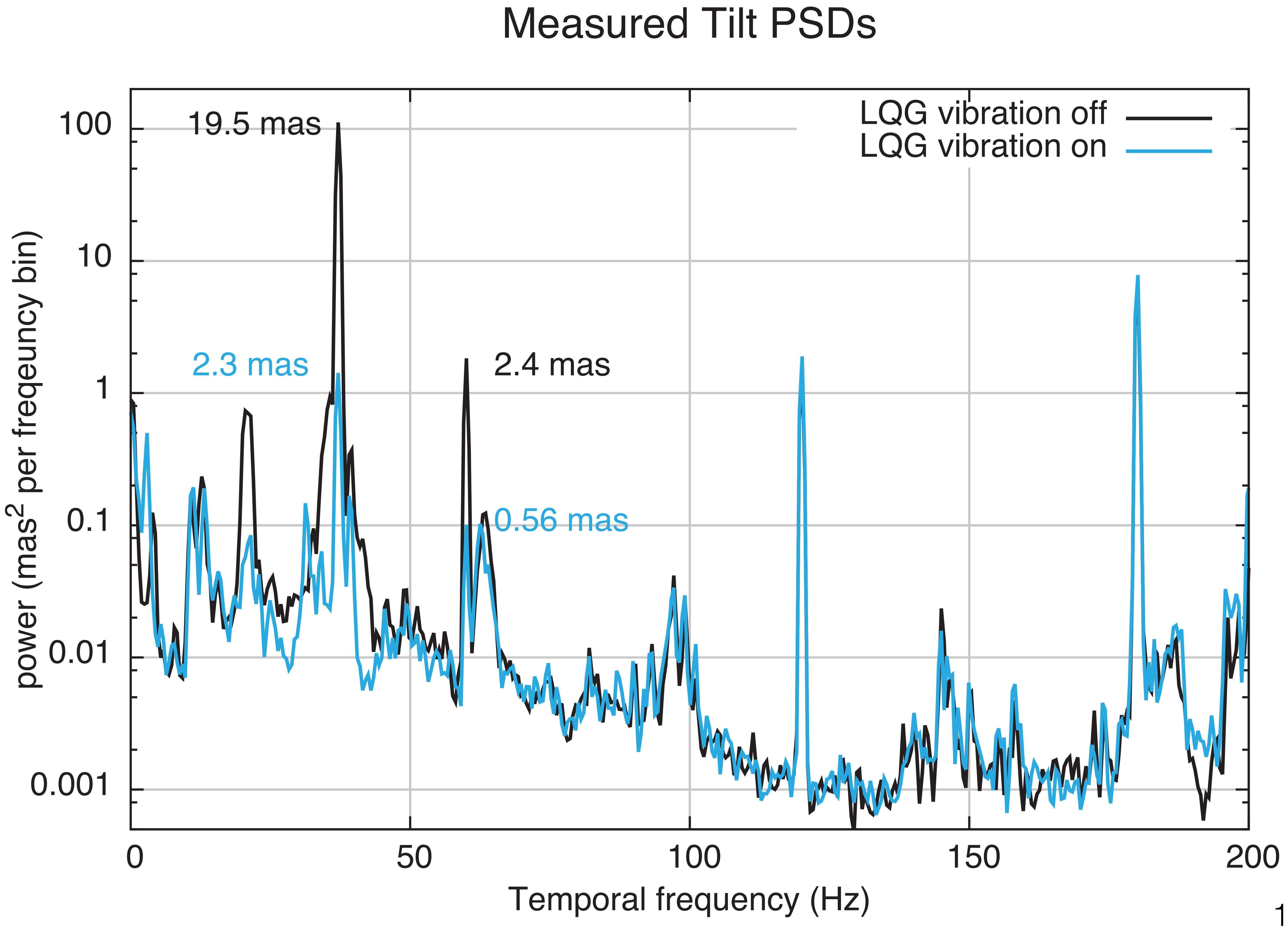

atmosphere errors
“bandwidth WFE”

photon/read noise
“noise WFE”

# Vibration analysis example: faulty fan

**Poyneer+, Appl Opt, 2016**



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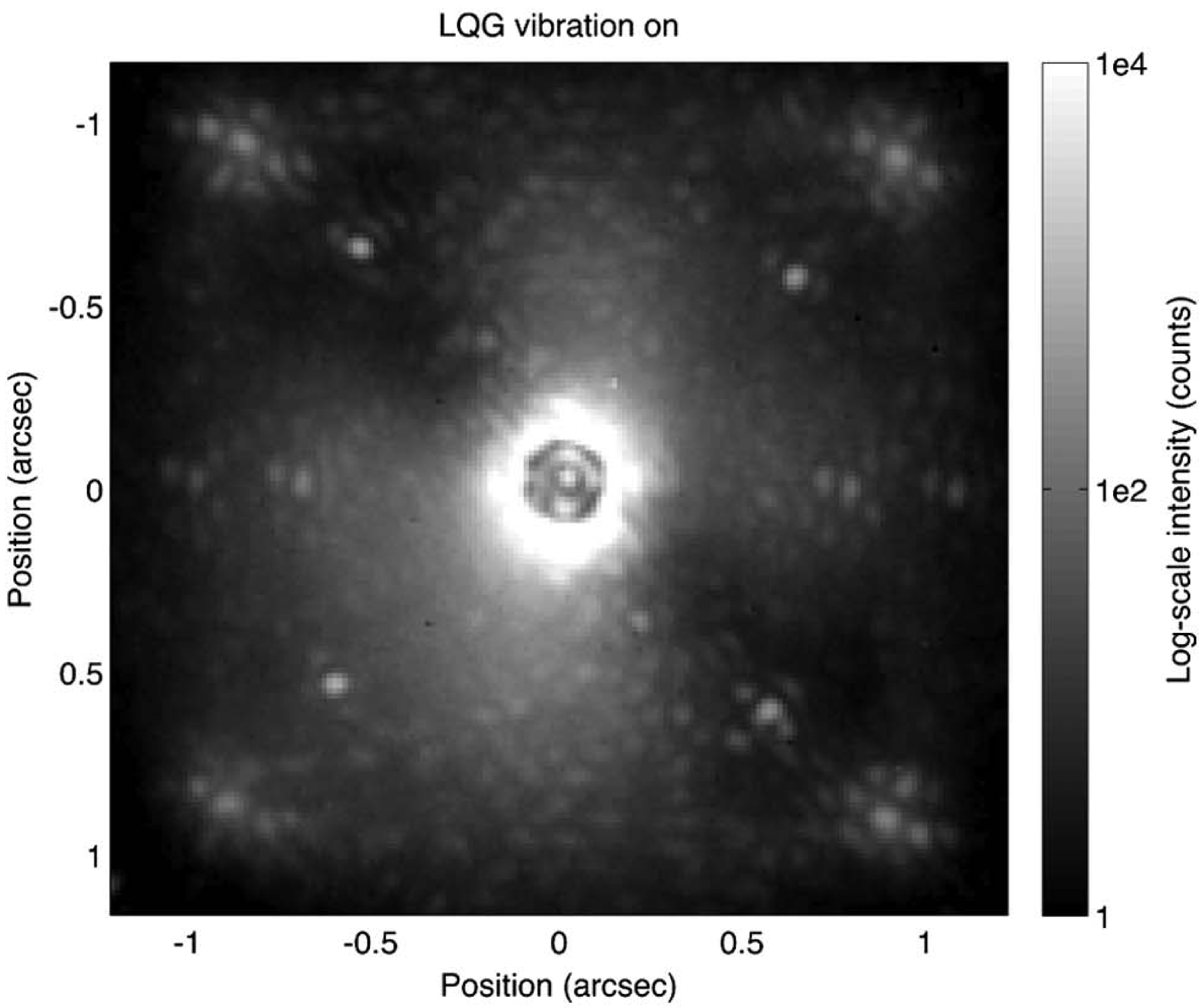
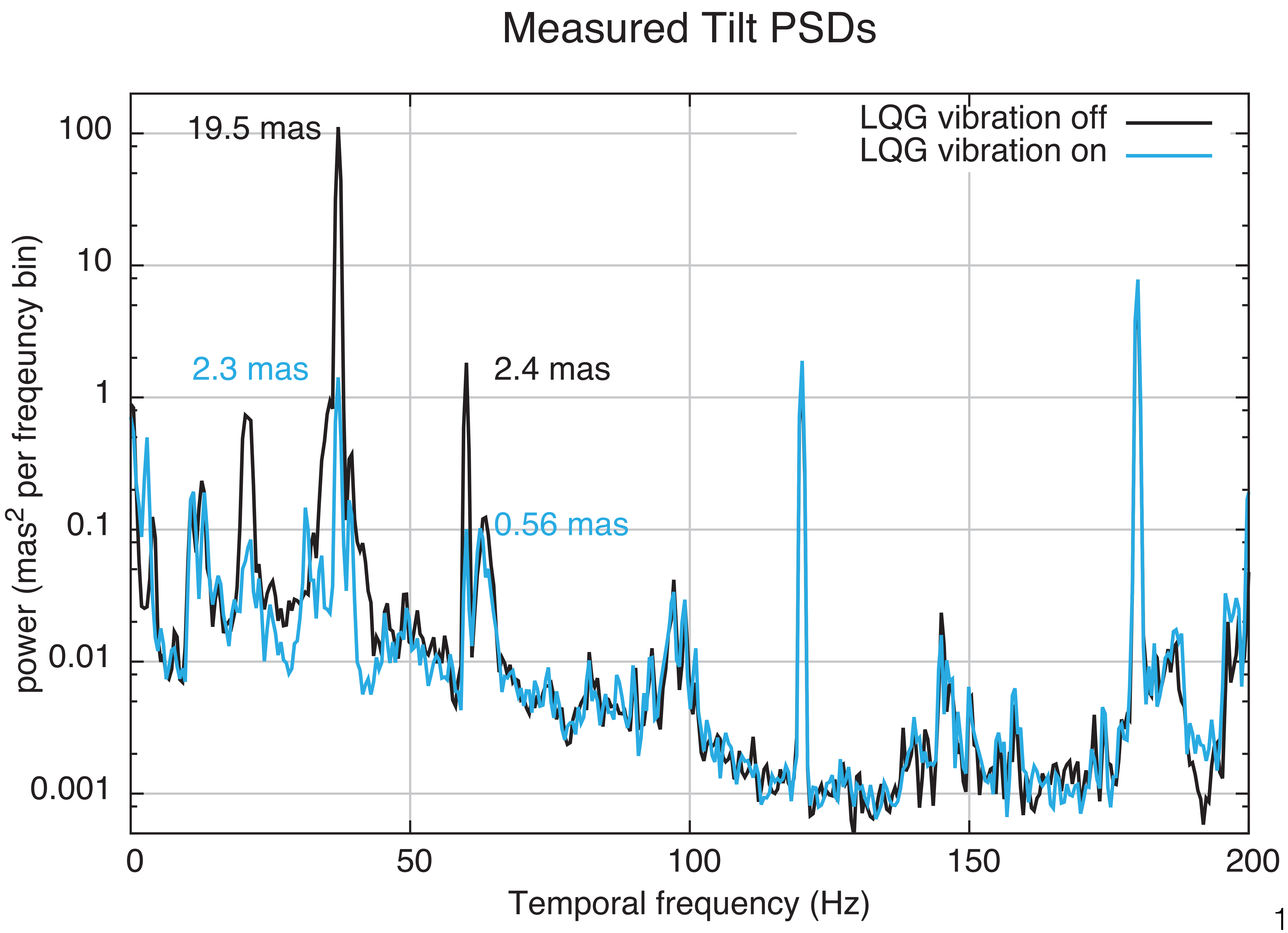
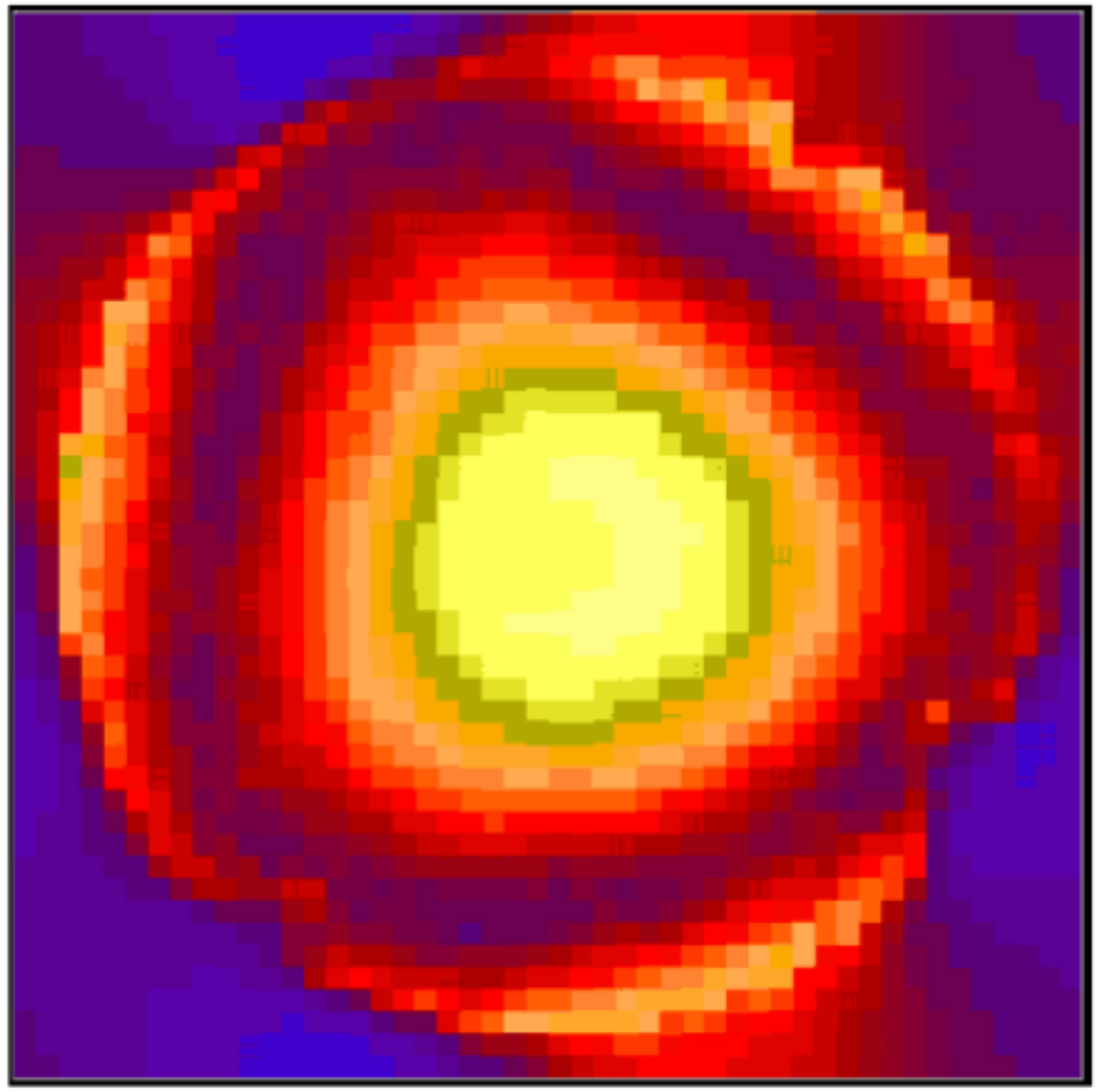
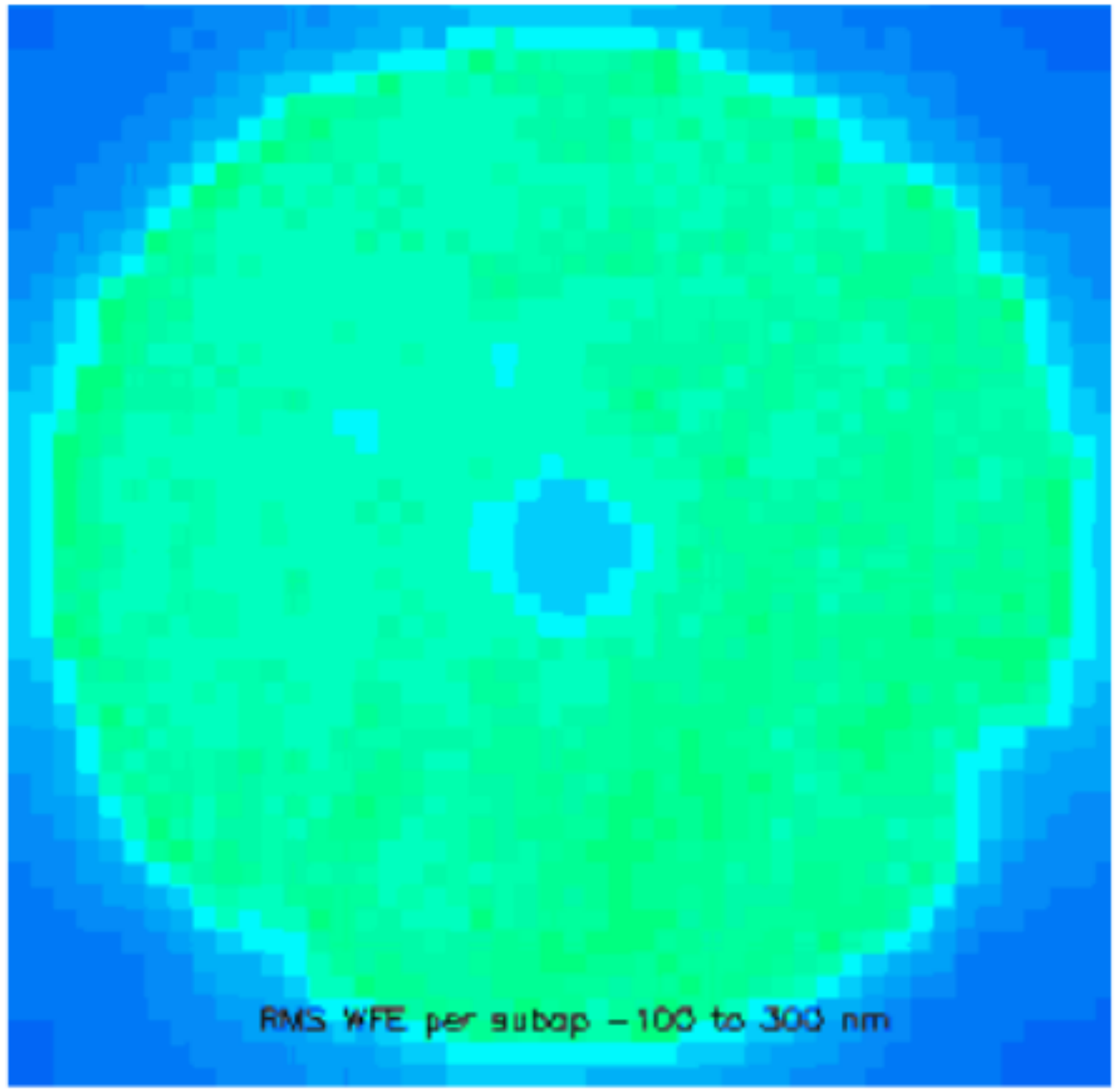


# Example: cryocooler controller replace to mitigate M1 60Hz coupling

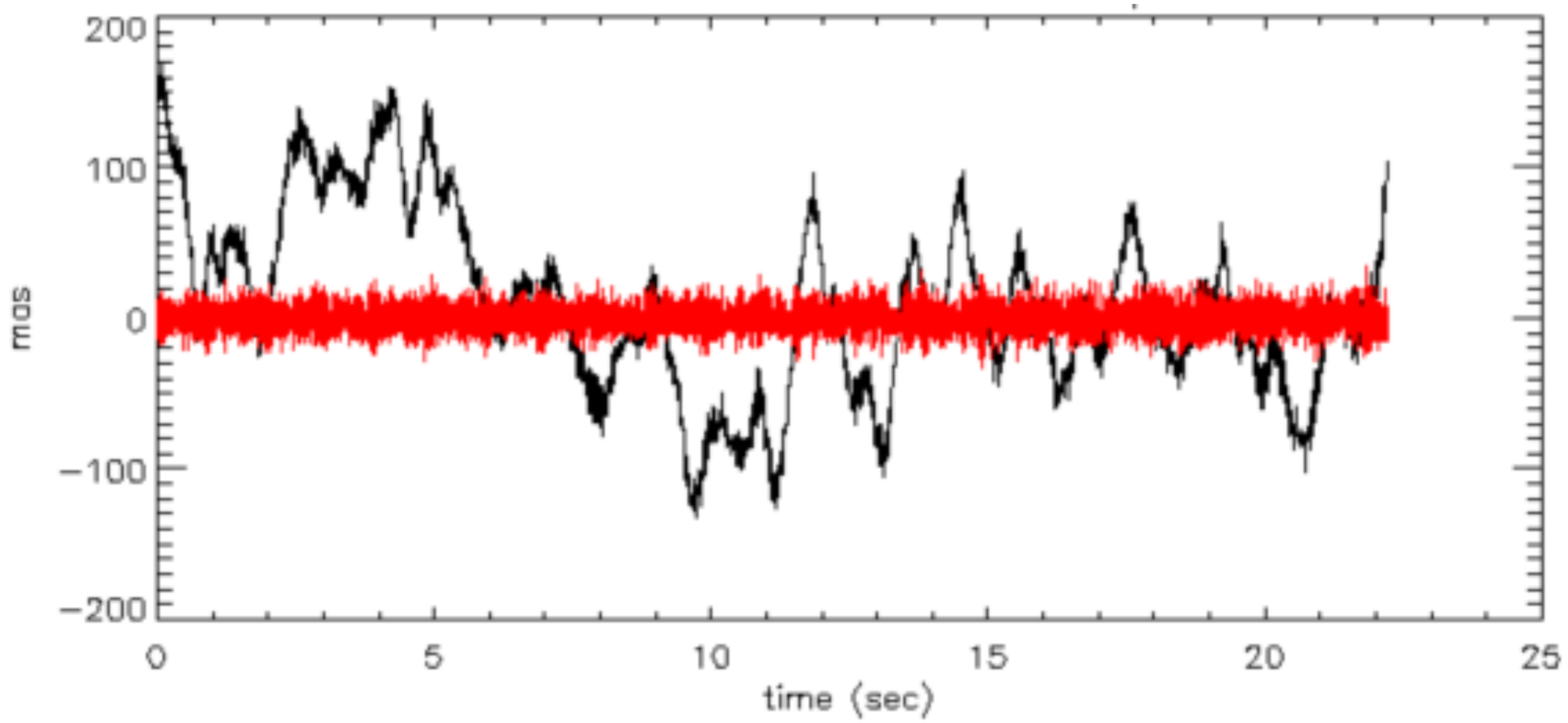


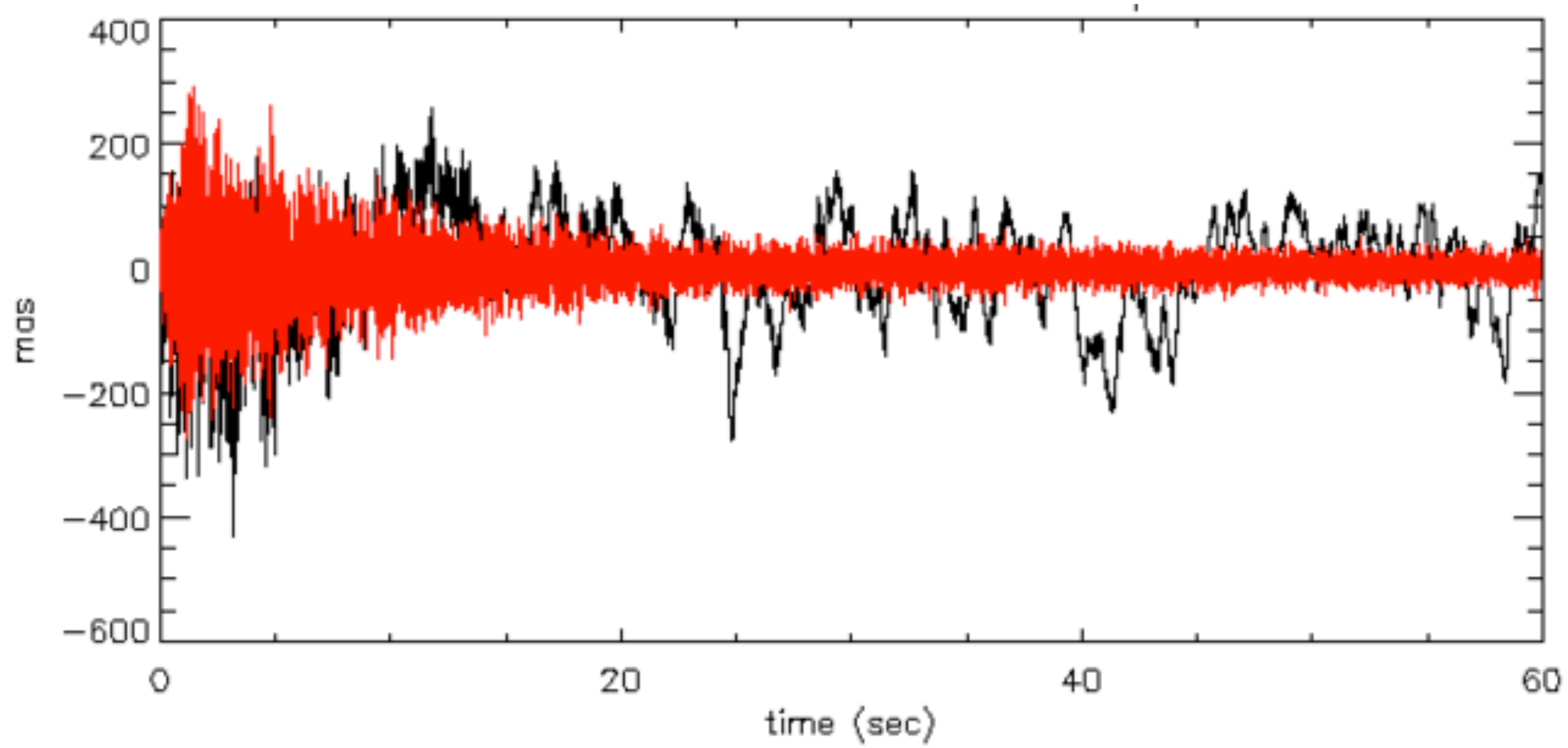



**Hartung+, SPIE, 2014**

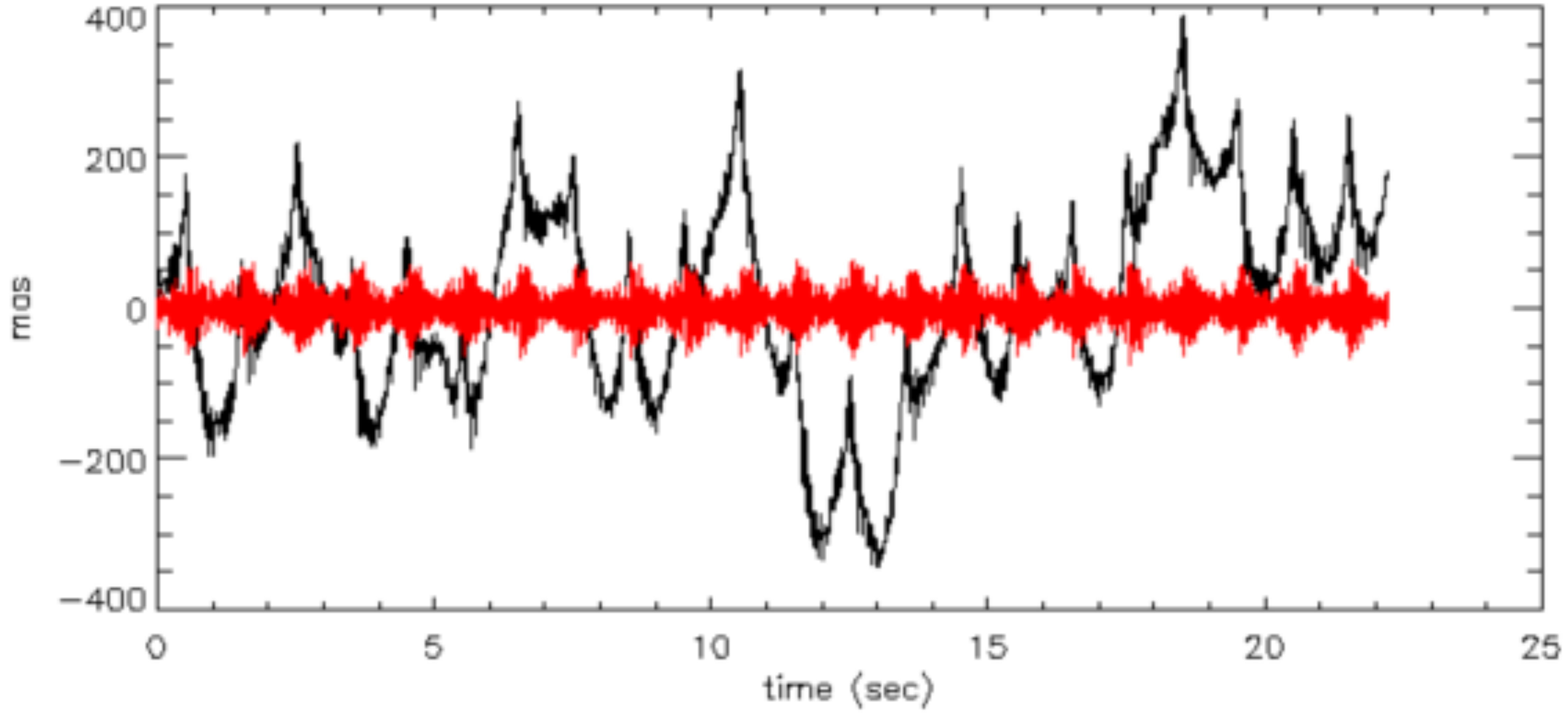
# Telescope tracking

# Earthquake

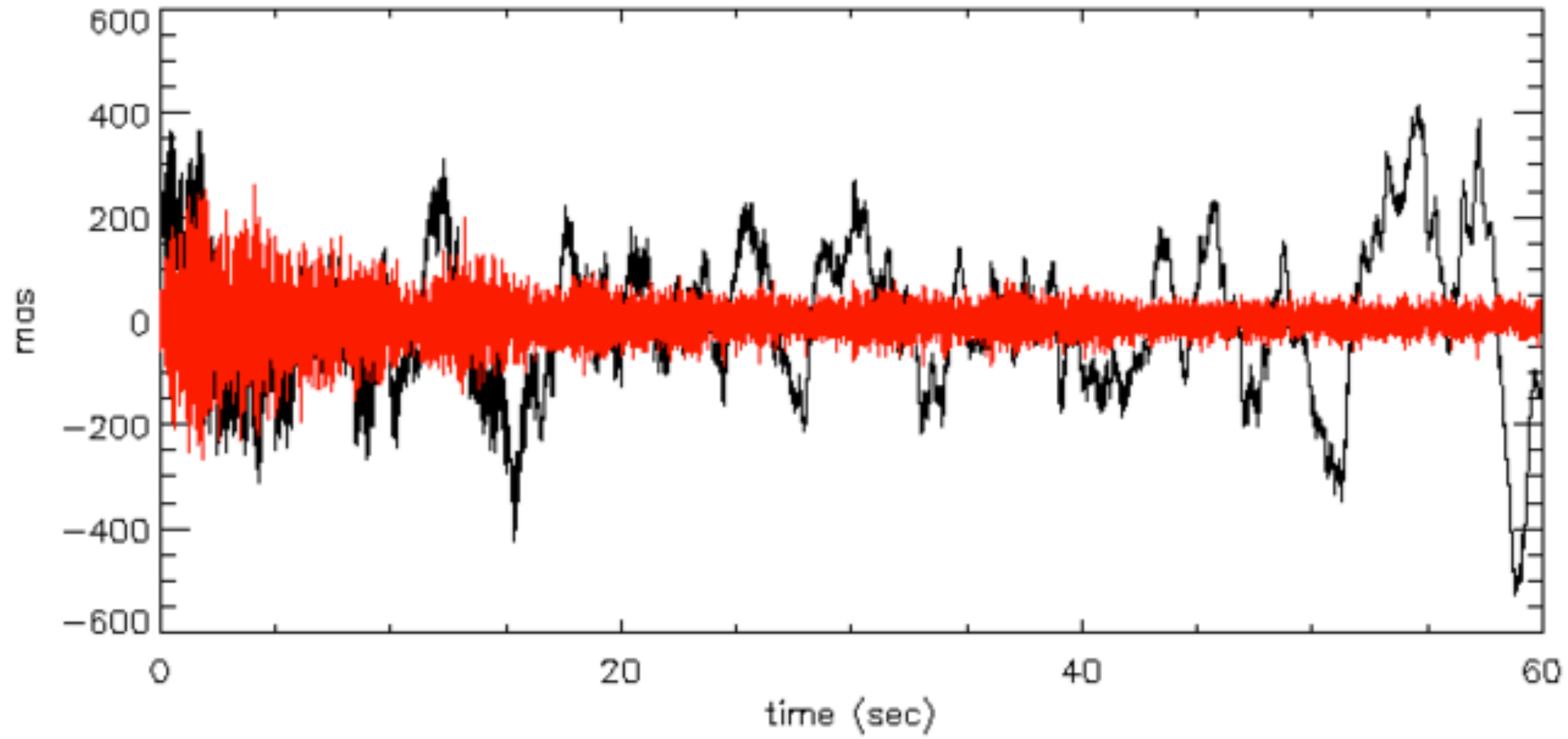



_When_2018.3.25_5.38.25 Tilt

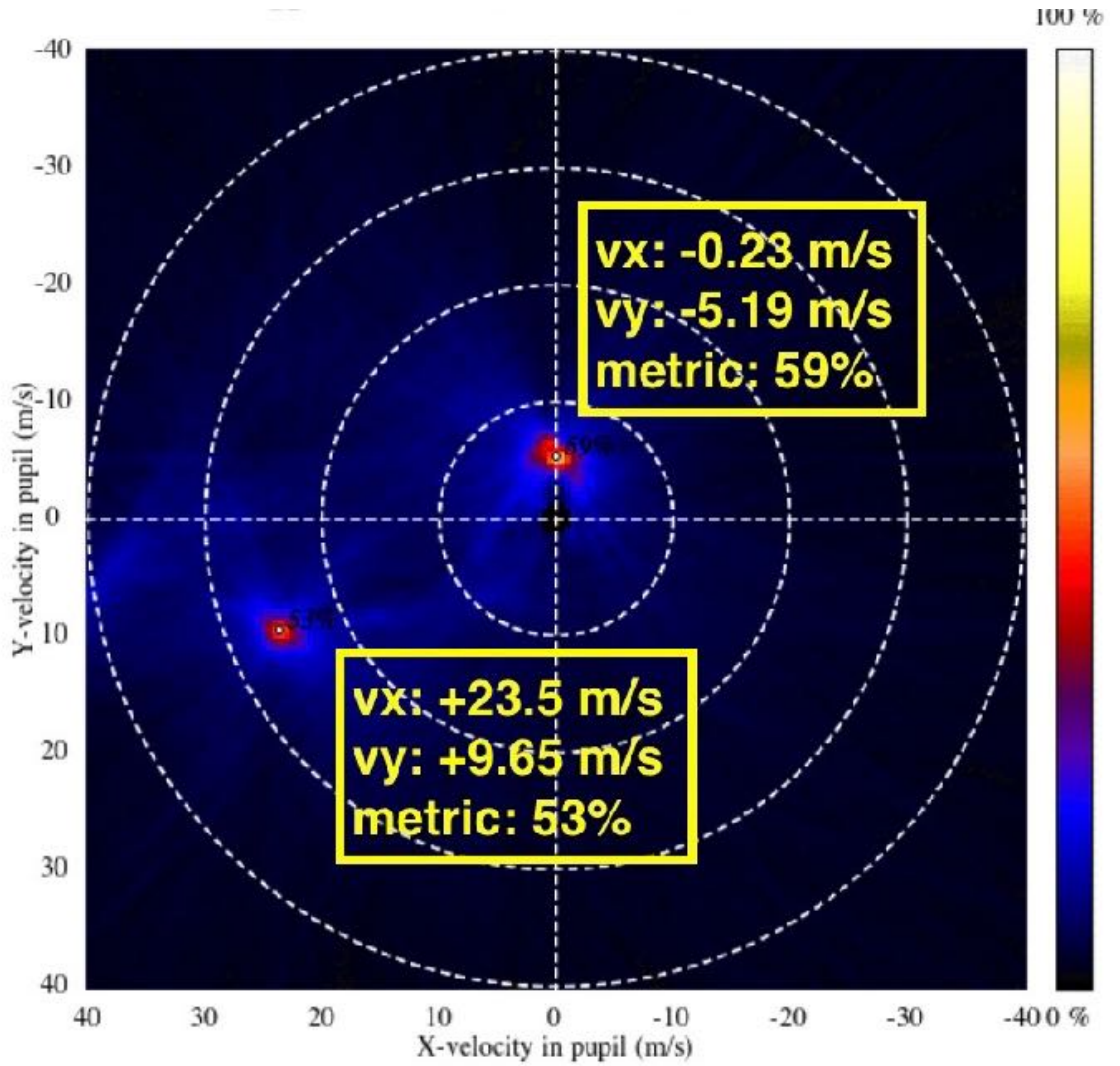



_When_2016.1.28_4.44.51 Tilt



# Tangent: site characterization

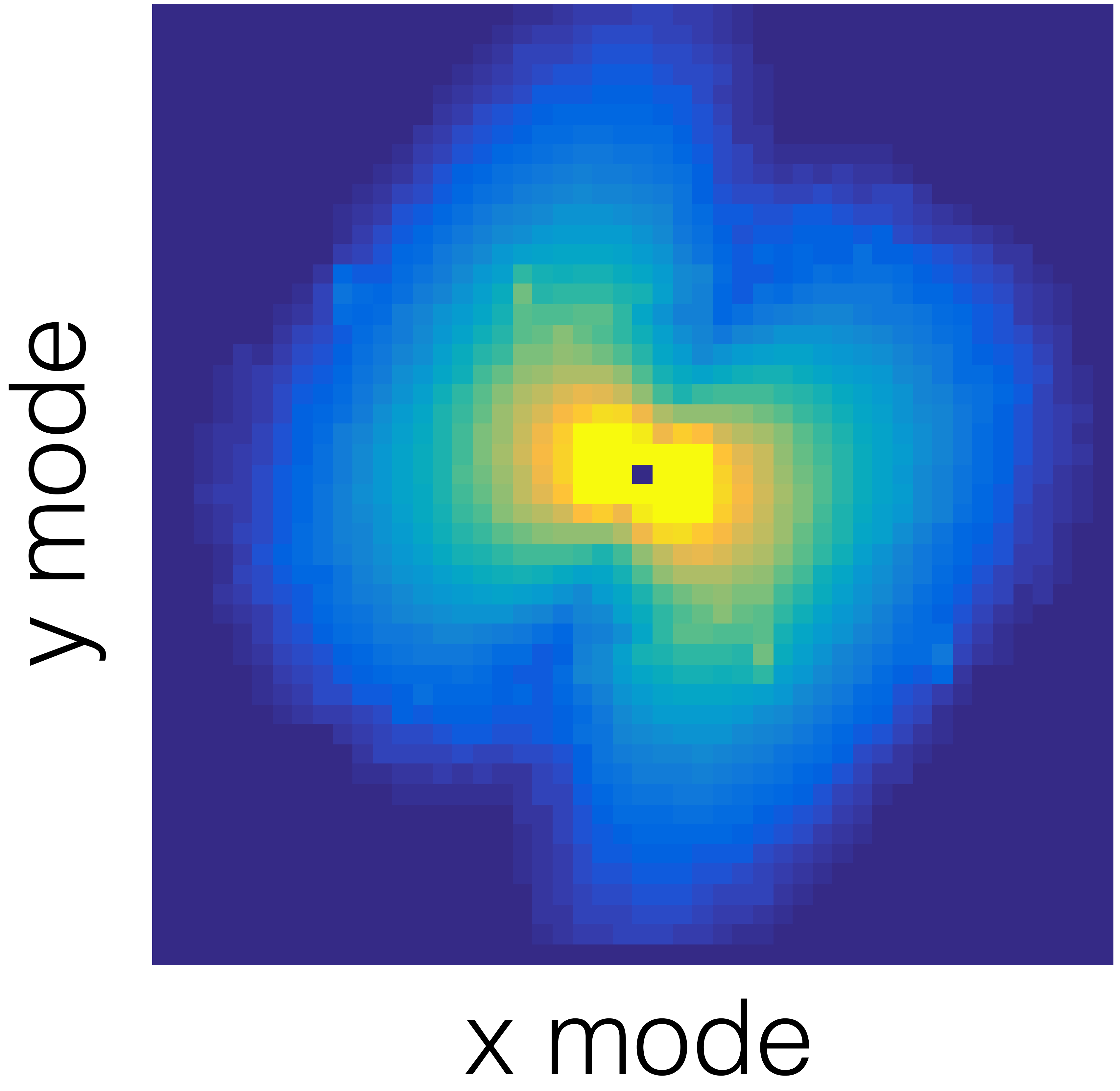
- Regular AO telemetry = regular site monitoring  (postprocessing required!!)
- Compare to observatory MASS, DIMM, etc.
- planning upgrades &/or new instruments (AO and seeing-limited)
- What datasets exist for other AO instruments and/or sites?




Sri Srinath - SPIE 2016
Adam Snyder - SPIE 2016

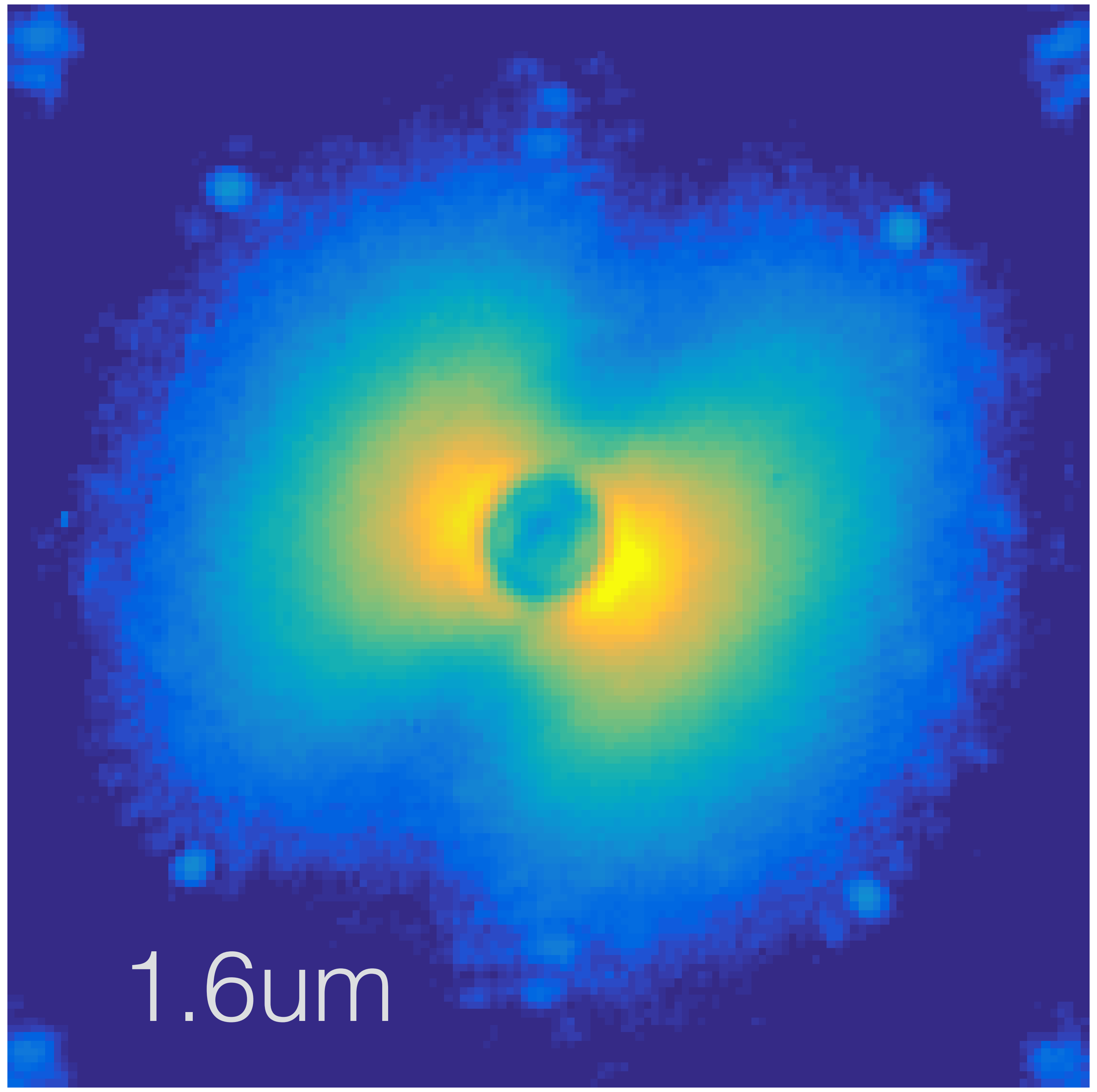
# Reconstructed WFE ~ GPI IFS frames

**pseudo-closed loop**
**WFE$^2$ [nm$^2$]**



2016.2.29_22.52.44

**IFS img**

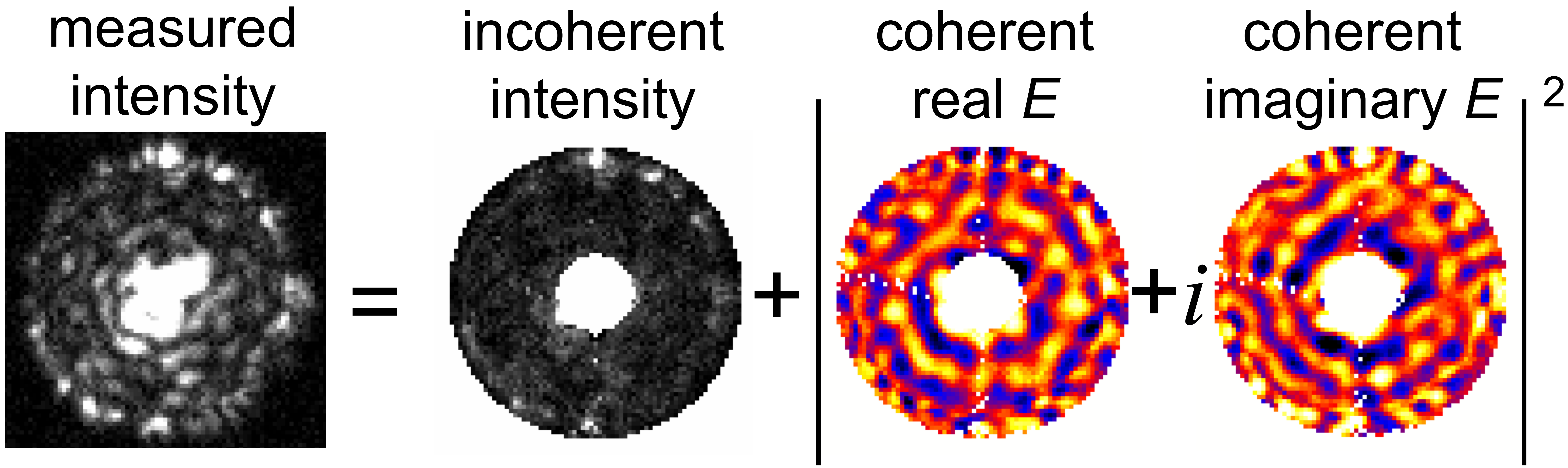



S20160301S0059_spdc

# telemetry for WFIRST CGI

**Eric Cady**

- LOWFS : full rate images saved
    - realtime x/y centering location of star in every science frame
    - contribution from Z2-Z11 = input to PCA?
- HOWFS uses science camera images themselves



# What AO telemetry do we actually save now?

- most AO data isn't saved!
  - data rate of 100MB to >1GB / minute for high-order systems
  - manually triggered sets. Few sec to a few min, a few times per target. Sparse sampling!
- lots of AO data is unprocessed!
  - pipelines, databases required but not often allocated resources
  - Design systems for simplified analysis? (eg: Fourier basis sets?)

# What is the minimal AO data we need to save?

- Analyze system performance?
- Complement focal plane WFS?
- Complement data reduction?
- What cadence?
- Save everything? Realtime process?
- S/N & error tolerance?
- ?

*ground vs. space?*

# How to use current systems?

- Reach specs on *current* systems
    - Develop AO telem pipelines & infrastructure
    - Identify factors limiting *astrophysics*, not WFE
- What can we test with existing systems?
- ??